OFFICE OF THE CHIEF
OF NAVAL RESEARCH
Arlington, Virginia 22217-5660

OCNR 11292-17
August 1992

COGNITIVE AND NEURAL SCIENCES DIVISION

1992 PROGRAMS

OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VA 22217-5660

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 92	10/1/91 to 9/30/92

4. TITLE AND SUBTITLE

COGNITIVE AND NEURAL SCIENCES DIVISION 1992 PROGRAMS

5. FUNDING NUMBERS

PE 61153N

6. AUTHOR(S)

Edited by Willard S. Vaughan. Special thanks to Ms. Lisa Jirousek.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Office of Naval Research
Cognitive and Neural Sciences Division
Code 1142
Arlington, VA. 22217-5660

8. PERFORMING ORGANIZATION REPORT NUMBER

114292-17

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

This is a compilation of abstracts representing R&D sponsored by the ONR Cognitive and Neural Sciences Division.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release;
Distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report documents R&D performed by Principal Investigators under the sponsorship of the ONR Cognitive and Neural Sciences Division during fiscal year 1992.

14. SUBJECT TERMS neural networks, neural plasticity, perception, cognition, learning and memory, knowledge acquisition, motor control, sensory information processing

15. NUMBER OF PAGES 252

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

FOREWORD

This booklet describes research carried out under sponsorship of the Cognitive and Neural Sciences Division of the Office of Naval Research (ONR) during fiscal year 1992. The Division's research is organized in three programs: Cognitive Science, Perceptual Science and Biological Intelligence. Each program is described by an overview which is followed by thematic clusters of related efforts. Each cluster is described by individual projects which were active during 1992.

This is one of several means by which we communicate and coordinate our efforts with other members of the research-sponsoring and research-performing communities. We encourage your comments about any feature of this booklet or about the programs themselves. If you wish further information, please do not hesitate to contact members of the staff listed in the Introduction. We welcome your interest in our programs and hope that you will continue to keep us informed of related research efforts.

W. S. VAUGHAN, JR.

CONTENTS

INTRODUCTION

Cognitive and Neural Sciences Division programs are carried out under contracts and grants awarded on the basis of proposals received in response to a Broad Agency Announcement in the Commerce Business Daily. Proposals are evaluated on the scientific merit of the proposed research, the facilities available for its conduct, the competence of the principal investigators, and relevance to Navy needs. The elements that shape our research program are scientific gaps and opportunities, and operational needs identified in Navy planning documents. Our overall aim is to support quality science for the good of the Navy and the nation.

Cognitive and Neural Sciences programs develop fundamental knowledge about human capabilities and performance characteristics which guide Navy and Marine Corps efforts to improve personnel assessments for selection and classification, training, equipment and system designs for human operation and maintenance. One goal is to provide scientific underpinning for more accurate prediction and enhancement of human performance in training and operational environments. A second goal is to understand the neurobiological constraints and computational capabilities of neural information processing systems as guides to design of future teleoperated and robotic systems. The Division has core programs in cognitive, perceptual and neural sciences which seek to understand human behavior at successively deeper levels of analysis. In addition, several Accelerated Research Initiatives (ARI) are underway which complement and extend research topics of interest to the core programs.

Most of the programs are basic in nature, with a selected augmentation of exploratory development effort. This mix of basic and applied research is developed and managed by the Division staff with the able assistance of the other ONR scientists and with helpful guidance and advice from representatives of various Navy and Marine Corps activities. The programs seek to involve innovative civilian scientists in areas of research relevant to Navy and Marine Corps interests, and by so doing provide new perspectives, new insights, and new approaches to naval manpower, personnel, training, equipment and system design problems. This arrangement provides channels for information to flow back and forth between the civilian research community and the naval community, each keeping the other abreast of new developments. The emphasis is on the creation and exploitation of a cumulative scientific knowledge base upon which new technologies can be developed to improve effectiveness of Navy and Marine Corps men and women.

Continuous efforts are made to coordinate the Division's research program with other ONR Divisions, with in-house Navy Laboratories and Centers, and with the research sponsored by other services and other agencies. We work closely with Technology Area Managers in the Office of Naval Technology (ONT), and with their Block Managers in Navy Laboratories and Centers to facilitate transitions from basic to applied research.

The Cognitive and Neural Sciences Division is part of the Life Sciences Directorate, which also includes the Biological Sciences Division. Dr. Steven F. Zornetzer is Director of the Life Sciences Directorate, and Captain James C. Coolbaugh is the Deputy Director for Life Sciences.

DIVISION STAFF

The members of the staff of the Cognitive and Neural Sciences Division are listed below:

DR. W. S. VAUGHAN, JR., DIVISION DIRECTOR
Telephone: (703) 696-4505

Cognitive Science Research Programs

Dr. Susan E. Chipman, Program Manager
Dr. Terry T. Allard
Telephone: (703) 696-4318

Perceptual Science Research Programs

Dr. Harold L. Hawkins, Program Manager
Dr. Teresa A. McMullen
Telephone: (703) 696-4323

Biological Intelligence Research Programs

Dr. Joel L. Davis, Program Manager
Dr. Thomas M. McKenna
Telephone: (703) 696-4744

COGNITIVE SCIENCE

The Cognitive Science research program of the Office of Naval Research aims to provide a theoretical understanding of the human learner and performer in the domain of complex cognitive skills. This general goal unfolds into several interrelated more specific objectives. First, to provide a theory of the fundamental characteristics of the learner and performer as an information processing system, including a theory of the basis of individual differences in cognitive abilities. Second, to provide a theory of the nature of acquired knowledge and skill involved in performing complex problem-solving and decision-making tasks. Third, to provide a cognitive learning theory that can account for the way in which such complex, structured bodies of knowledge and skill are acquired. Fourth, to provide a precise theory of instruction, founded on cognitive theory, to be used to guide effective education and training of complex cognitive skills such as those involved in performing Naval duties. Finally, this research program aims to provide theoretical foundations for personnel testing and assessment. Research in Cognitive Science is expected to lead to the design of efficient instructional systems across a range of content domains of interest to Navy and Marine Corps training programs, to the development of efficient and accurate computer-based personnel assessment systems, and to the design of expert advisory systems compatible with human intellectual characteristics.

The Human Learner: Cognitive Architectures

Research aimed at discovering and characterizing the stable features of the human learner emphasizes later stages of information processing--cognition rather than perception. This cluster of projects is developing theories for the functional architecture of cognition, including subtheories for memory and elemental cognitive processing operations. Current priorities emphasize the use of neural evidence to constrain theories of cognitive architecture. Results of research in this cluster will provide sound theoretical bases for personnel testing and selection, and for the individualization of instructional treatments based on accurate diagnosis of cognitive capacities.

Knowledge, Skill and Expertise

Research on knowledge and expertise aims at formal theories of complex human skill. The program emphasizes the expression of theories in the formal languages provided by mathematics and computer science and includes empirical tests of developed models. Projects target a wide range of complex skills, emphasizing problem-solving and decision-making, so that a general theory can evolve. Research results are intended to provide a general model for skill analysis that can be used to design appropriate training, testing or expert advisory systems.

Learning and Instruction

Research on Learning and Instruction aims to produce a knowledge-rich theory of learning that integrates results of work in the prior clusters and develops a coordinated instructional theory that explains how to produce change -- learning -- in desired directions. Under the Knowledge Acquisition ARI, there is currently a major emphasis on AI-based models of complex human learning. Artificially intelligent, computer-assisted instructional systems as well as more conventional instructional settings are the application areas for the program. In addition, projects are supported which involve either fundamental advances in AI bases for intelligent tutoring or the use of intelligent tutoring systems as a laboratory for investigation into general issues of learning and instruction.

Model-based Measurement and Cognitive Diagnosis

This cluster has emphasized the development of item-response theory, the mathematical apparatus underlying modern testing technology, including computerized, adaptive testing. Emphasis is now shifting to developing a scientific basis for the design of test content, building upon the foundation of recent advances in cognitive science. This research provides the technology base for improvements to the testing components which constitute the heart of Navy and Marine Corps personnel and training systems in which case-by-case decisions are made. This includes systems for personnel selection and classification, for career counselling, for the design/selection of instructional interventions, for performance aiding, for certification and for performance evaluation. As the Navy modernizes those systems to take advantage of potential improvements in a computer-based workplace, this research is providing the wherewithal for improvements to those systems through improvements to their measurement components.

PERCEPTUAL SCIENCE

Research in the Perceptual Science program emphasizes issues of perceptual primitives and their representations and transformations in the domains of vision, audition, touch and manipulation, multimodal integration, and the control of motor activity. Research results are expected to transition to Navy and Marine Corps systems in the form of enhanced technologies for human factors engineering, machine vision, acoustic signal classification, adaptive filtering, and dexterous manipulators for autonomous and teleoperated vehicles.

Vision and Visual Attention

Vision is viewed as a computational process and projects in this cluster emphasize interdisciplinary approaches. Mathematical models are constrained by neurophysiological evidence and tested by psychophysical experiments. Focus is on modeling early, intermediate, and late-visual processes that construct and recognize visual forms and integrate these forms into complex visual representations. A second thrust inquires into the nature of neural mechanisms of control. In their more evolved forms, visual systems contain special modulatory mechanisms that enable them to adjust quickly and adaptively to momentary fluctuations in environmental demand. These are the neural control mechanisms underlying attention and arousal. Interest within this cluster is on empirical research in human visual performance, neuroanatomy, neurophysiology, and neuropsychology aimed at investigation of the control structures and circuitries underlying visual attention, and the neurochemical modulators governing attentional processing.

Audition

In audition, research projects examine the processing of steady state, transient, and reflected acoustic signals, and model the concurrent processing of complex sound properties and interactions. Current emphasis is on understanding and modeling the classification processes of human listeners, augmented by neurophysiological evidence from other biological species with interesting auditory capabilities and the signal processing capabilities of artificial neural nets.

Haptics and Sensory Guided Motor Control

Sensory guided motor control is a new area of interest in Perceptual Science. Emphasis is on experimental and theoretical studies of the fundamental issues of coordinated motor function, including the computational bases of force control, and the timing and sequencing of action. Special emphasis is given to work investigating the processes through which sensory information functions as an adaptive guide to coordinated action. Interdisciplinary research is encouraged in psychology, neuroscience, and computer science to achieve an understanding of sensory guided motor control that will contribute toward enhancement of action

adaptability within robotic systems.

The processing of tactile and kinesthetic information in object recognition is a related area of interest in this cluster. Priority research issues include the identification of perceptual primitives, neural network models for tactile processing in somatosensory centers, and perceptual mechanisms that mediate inferential judgments about object properties, classifications and function. Interdisciplinary research is encouraged in psychology, neurophysiology and computer science with the goal of understanding the haptic system in order to provide future robotic devices with intelligent hands.

Human Factors Technology and Biopsychometric Assessment

The projects described in this section are Exploratory Development efforts which extend our basic research thrusts in acoustic signal analysis, teleoperation of remote devices, decision making and the neural basis of attention. These projects connect basic and applied research activities, enable collaborations between academic and Navy laboratory scientists, and drive research toward products of value to the operational Navy.

BIOLOGICAL INTELLIGENCE

Biological Intelligence programs foster research to elucidate the organization, structural bases, and operational algorithms characterizing information processing networks within neural systems. The goal is to uncover neural architectures and algorithms that can profitably be emulated technologically to yield artificial information processing capabilities of kinds now unique to biological systems. These neural architectures may be derived from either sensory-, motoric- or cognitively-related structures. Overall, the program of research seeks to uncover the organizational principles and operational rules exploited within neural networks to compute intelligent functions, and to emulate these network characteristics within electronic information processing systems.

Computation in Large Neural Networks

This research examines the global dynamics of biological neural networks composed of large numbers of neurons. The goal of this research is a formal description and simulation of the biological computations underlying information processing, learning and cognition in order to design electronic information processing systems with these network characteristics.

Single-Neuron Computation

Real neurons exhibit a much greater computational complexity than the processor elements of most artificial neural networks. Moreover, current neurobiological research shows that adaptive nets can emerge from synaptic modification rules that operate locally, rather than globally. The research in this program would address such issues as the computations performed in neuronal dendritic trees, Hebbian rules, and the neuron as a neuronal network. The goal of this research would be to develop modules, or sub-nets that capture the computational features of real neurons which could form the building blocks for a new generation of neural nets.

Synaptic Plasticity

A valuable property of biological intelligence is the ability to learn, remember and modify behavior on the basis of experience. Synaptic plasticity, the ability of neurons to alter the strength of synaptic connections, is the neural basis of learning an memory. This cluster of research explores the biochemical and membrane mechanisms of synaptic plasticity which modify information processing and alter network dynamics.

Sensory Neuroscience and Signal Processing Technology

This research is concerned with the functional organization of sensory systems, the computations performed in sensory systems, and the adaptive plasticity of these networks evident at the level of the receptive field. Sensory processing is studied in vision, audition, olfaction, touch and motor control. Pronciples of sensory neuroscience are implemented in neural networks for advanced signal processing and signal classification.

Neural Control of Locomotion and Movement

Research in this area is focused on computational and neurophysiological approaches to motor control of limbs at the level of the cerebellum, basal ganglia, and motor cortex. An emerging focus of this program is locomotion control in legged invertebrates. The objective is to develop neural models based on the neuronal circuitry underlying legged locomotion in order to develop new controller architectures for autonomous legged robots.

MANPOWER, PERSONNEL AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM

This is an interdisciplinary program of exploratory development managed by Dr. Stanley Collyer in the OCNR Office of Naval Technology. Scientific Officers for these projects are located in the Cognitive and Neural Sciences Division and in the Mathematics Division of the Office of Naval Research. Projects which are closely related to the primary emphases of the Cognitive and Neural Sciences Division have been grouped with the related basic research projects, identified by the notation that funds have been provided by ONT Code 222. In this section, there are descriptions of projects addressing unique priorities of the MPT program. This report includes descriptions only for those contracts managed by a Scientific Officer in the Cognitive and Neural Sciences Division.

This program is closely coupled with the operating arms of the Navy and Marine Corps through the mechanism of a planning committee, whose members include ONR Scientific Officers, the Naval Civilian Personnel Command, the Naval Military Personnel Command, the Navy Recruiting Command, the Navy Personnel Research and Development Center, several directorates in the Office of the Chief of Naval Operations, and the Navy Secretariat.

UNIVERSITY RESEARCH INITIATIVE: DECISION MAKING IN HIERARCHICAL TEAMS

This is a special program of basic research developed under the Department of Defense Research Initiation Program within the University Research Initiative. Emphasis is on theory development, variable definition and measurement approaches, modeling and experimentation to deepen our understanding of how coordination is achieved and maintained by hierarchical decision-making teams in stressful environments. This section characterizes the six awards made in FY90 to explore issues in hierarchical team decision making.

A parallel program of exploratory development research was begun by ONT Code 222 during FY90, Tactical Decision Making Under Stress (TADMUS). Mechanisms to insure close coordination between these two programs have been put in place to strengthen transition opportunities.

STRESS AND PERFORMANCE

This program is a core initiative of the Division of Cognitive and Neural Sciences that spans the three CNS programs in Cognitive Science, Perceptual Science, and Biological Intelligence. The primary objective of the program is to relate the physiology of stress to psychological performance. Research supported by the program includes: 1) brain mechanisms of memory that may be differentially affected by stress, 2) individual differences in stress reactivity, 3)

predicting indiviedual performance under stress, and 4) modeling team decision-making under stress. Emphasis on understanding basic biological and behavioral constituents of the human response to psychological stressors. This program complements the URI-sponsored program: Decision-making in Hierarchical Teams and the TADMUS (Tactical Decision Making Under Stress) program of the Office of Naval Technology.

COGNITIVE SCIENCE

THE HUMAN LEARNER: FORMAL COGNITIVE ARCHITECTURES AND NEURO-COGNITIVE SCIENCE

TITLE: Cognitive Determinants of Individual Differences in Learning

PRINCIPAL INVESTIGATOR: Philip L. Ackerman
University of Minnesota
Department of Psychology
(612) 625-9812

R&T PROJECT CODE: 4422543 CONTRACT NO: N0001489J1974

Objective:
The objective is to investigate the relationship between measures of various psychometric abilities and the course of acquisition of skills of various types: perceptual-motor skills, cognitive skills with minimal perceptual-motor components, and fine motor coordination skills.

Approach:
Nine experiments are planned, using appropriately selected skill learning tasks, to examine such questions as the role of cognitive abilities in determining skill transfer, the possibility of changes in measured abilities as a consequence of practice in a skill and the role of various psychometric abilities in determining asymptotic performance. A wide variety of psychometric ability measures will be taken and subjects will undergo prolonged training in order to develop high, asymptotic levels of skill. Tasks studied include variants of a simulated air-traffic control task.

Progress:
In the air traffic control task, which is an inconsistent information processing task requiring centrally controlled processing throughout acquisition practice, correlations with general ability were found to be stable and high over practice. Spatial abilities accounted for an increasing amount of variance over practice, reflecting the spatial nature of the task after the general rules of operation are acquired. Correlations with perceptual motor abilities increased with practice. The last was particularly true for the more consistent components of the overall task.

Reports:
Ackerman, P.L. (1990) A correlational analysis of skill specificity: Learning, abilities, and individual differences. JEP: General, 117, 288-318.
Ackerman, P.L. (in press) Predicting individual differences in complex skill acquisition: Dynamics of ability determinants. J. Applied Psychology.

TITLE: Use of Rational Analysis to Design an Architecture for Learning and Problem Solving

PRINCIPAL INVESTIGATOR: John R. Anderson
Carnegie-Mellon University
Department of Psychology
(412) 268-2788

R&T PROJECT CODE: 4422559 CONTRACT NO: N0001490J1489

Objective:
The primary purpose of this grant is to undertake a revision of the ACT* theory of human cognitive architecture, taking into account the implications of a rational analysis of the environmental requirements on human cognition that the PI has already conducted. Empirical studies of problem solving will also be conducted to provide additional constraints on the theory.

Approach:
The lessons arising from a rational analysis of the requirements of a number of theoretically important cognitive tasks will be reflected in a new and improved formulation of the ACT class of computational theories of human cognition. In addition, new empirical problem solving studies will be conducted in order to provide guidance to how the theory should treat learning in situations in which rules are probabilistic in character, not explicitly taught but induced without instruction, and those which involve explicit management of costs and gains.

Progress:
Substantial progress has been made in revising the ACT theory of cognitive architecture to conform with the rational analyses of the requirements of cognitive tasks that Anderson recently completed: the new architecture is called ACT-R. So far, tested differences in simulation performance are minimal. After a further year of testing, publication of ACT-R as a documenting book and accompanying software disk is planned, in order to make this cognitive simulation system widely available.

Report:
Anderson, J.R. (1990) The Adaptive Character of Thought, Hillsdale, NJ: Erlbaum.

TITLE: Working Memory in Visual Problem Solving

PRINCIPAL INVESTIGATOR: Patricia A. Carpenter
Carnegie-Mellon University
Department of Psychology
(412) 268-2091

R&T PROJECT CODE: 4422575 CONTRACT NO: N0001492J1209

Objective:
This project aims to further develop a computational model of constrained working memory capacity, emphasizing the incorporation of improved understanding of the limitations on capacity to deal with information of a visual character.

Approach:
Psychological experiments will be conducted to examine the working memory demands of tasks requiring visualization, such as visualization of mechanical motion or visual reasoning tasks. The interaction of these memory demands with requirements for goal management memory will also be explored to yield insight into the domain specificity or generality of working memory limitations. Pupil dilation will be explored as an indicator of on-going changes in mental workload.

Progress:
This grant is new in FY92.

TITLE: The Immediate Interaction Cycle: Generality of Mechanics and Learning to Perform

PRINCIPAL INVESTIGATOR: Bonnie John
Carnegie-Mellon University
School of Computer Science
(412) 268-7182

R&T PROJECT CODE: 4422556 CONTRACT NO: N0001489J1975

Objective:
To extend the Soar model of human cognitive architecture to account for the way in which interaction with perceivable and modifiable displays in the environment--such as diagrams or computer displays--serves to augment the limited working memory of human problem solvers and decision makers.

Approach:
Videotape protocols with chronometric data will be collected while people perform tasks which involve constructing and modifying displayed objects. The information in the videotapes will be the basis for constructing a simulation model of this "immediate interaction cycle" within the Soar theory of cognitive architecture.

Progress:
Somewhat surprisingly, it proved possible to model over 80% of user behavior interacting with a computer browser display in the terms of the earlier GOMS (goals, operators, method, selection) modeling scheme developed for modeling very routine user behaviors. Approximately 10% of user behavior was generate-and-test problem solving involved in setting the goals or objectives for more routine behavior and another 10% was reading comprehension activity outside the scope of the present effort. Only about 1% of behavior proved problematic for the model. Similar success was achieved in modeling the very rapid interaction of a computer game.

Reports:
John, B.E., Vera, A.H. & Newell, A. (1990) Towards real-time GOMS. School of Computer Science, Carnegie Mellon University. ONR Tech Report No. AD# A232028 (also CMU-CS-90-195).

Atwood, M.E., Gray, W.D. & John, B.E. (in press) Project Ernestine: Analytic and empirical methods applied to a real-world CHI problem. In: L. Gugherty & P. Polson (eds.) Human-Computer Interaction Interface Design: Success Cases, Emerging Methods, and Real-World Contexts.

TITLE: BRAINMAP -- A Database of Functional Neuroanatomy Derived From Human Brain Images

PRINCIPAL INVESTIGATOR: Jack L. Lancaster
Health Science Center at San Antonio
Research Imaging Center
(512) 567-5549

R&T PROJECT CODE: 442k007 CONTRACT NO: N0001491J1903

Objective:
This project aims to develop database systems which will make it possible to compare and combine research results on the functional anatomy of the human brain, both neuropsychology research on the effects of brain damage and functional imaging data from normal subjects. Two systems will be developed, a Macintosh/SuperCard database for results in the published literature and a Sun-based system for near-raw-data results of PET imaging studies. The latter will be interfaced to a PET image display/analysis environment.

Approach:
Data on brain locations of lesions or of foci of PET activity will be indexed in a 3-D coordinate system that has been previously developed for the analysis and combination of PET scan data, in addition to being indexed by conventional anatomical nomenclature. Behavioral conditions will be described in a multi-level list-driven schematization of the experimental conditions employed, in order to maximize clarity and objectivity. In order to reduce the PET image data to records of manageable size, it is partially reduced by examining regions showing change in cerebral bloodflow that are statistically significant outliers from the noise distribution.

Progress:
This project began very recently. Nevertheless, substantial progress has been made in developing the Macintosh side of the project. This includes a major change in the design approach which will unify the Macintosh and Unix-based sides of the project through the common use of versions of the Oracle database system and its SQL (Structured Query Language).

TITLE: Computational Modeling of Human Multiple Task Performance and Mental Workload

PRINCIPAL INVESTIGATOR: David E. Meyer
University of Michigan
Department of Psychology
(313) 763-1477

R&T PROJECT CODE: 4422574 CONTRACT NO: N0001492J1173

Objective:
The project aims to develop a computational production system model which can account for research results in the human performance literature concerned with multiple task performance. It also aims to provide an objective, theoretically sound approach to measuring the mental workload imposed on human operators.

Approach:
Early stages of the project will emphasize development of a production system computational model that can account for the results in the existing literature on multiple task performance. The initial approach will employ an assumption of unlimited parallel processing of productions (condition-"action" pairs) at the central executive level of cognition, with strategic elements accounting for apparent capacity limitations in combining tasks that do not involve obvious conflicts at the level of the perceptual and motor systems employed. Once the model has been formulated, experiments will be conducted to test critical predictions in novel experimental paradigms.

Progress:
This grant is new in FY92.

TITLE: Neural Systems Underlying Visual Recognition in Humans

PRINCIPAL INVESTIGATOR: Antonio R. Damasio
University of Iowa
Behavioral Neurology and Cognitive Neuroscience
(319) 356-4296

R&T PROJECT CODE: 442k002 CONTRACT NO: N0001491J1240

Objective:
To evaluate competing theories of normal visual cognition and perception by studying patients with focal brain injuries and differential deficits in visual object recognition and naming.

Approach:
Deficits in visual object recognition and naming will be studied in neurological patients with focal cerebral lesions. Subjects will be chosen from a large subject pool on the basis of lesion characteristics. Features of visual stimuli will be varied parametrically to identify and differentiate specific cognitive and perceptual mechanisms underlying behavioral deficits and normal visual processes.

Progress:
New stimuli for visual object recognition studies were generated and tested with both normal subjects and selected neurological patients. Preliminary results showed that color, context, and animation augment performance by patients with visual recognition deficits. Software was developed to analyze the geometry of natural and man-made visual stimuli used in previous studies. Preliminary studies showed that the human visual pathways process information in parallel systems based on the degree of curvilinearity of stimulus features.

Reports:
Damasio, A.R. and Tranel, D. Knowledge systems. *Current Opinion in Neurobiology*, 2. (in press).

Damasio, H., Kuljis, R.O., Yuh, W., Van Hoesen, G.W., Ehrhardt, J. (1991). Magnetic resonance imaging of human intracortical structure *in vivo*. *Cerebral Cortex*, 1: 374-379.

Damasio, H., Frank, R. (1992). Three-dimensional *in vivo* mapping of brain lesions in humans. *Archives of Neurology*, 49: 137-143.

TITLE: Twelfth Annual Carmel Conference

PRINCIPAL INVESTIGATOR: Emanuel Donchin
University of Illinois
Department of Psychology
(217) 333-2186

R&T PROJECT CODE: 442k009 CONTRACT NO: N0001492J1168

Objective:
Theoretical and methodological issues concerning the role of the hippocampus in human learning and memory were discussed and evaluated at this interdisciplinary workshop.

Approach:
A 5-day workshop will be conducted for a small group of scientists who use different technological approaches to the study of learning and memory. After a series of individual tutorials by recognized experts from several disciplines, the participants will break into four working groups to discuss and prepare a response to a set of detailed questions about one of four topics. The responses of the four panels will be presented during the last two days of the meeting.

TITLE: Functional Mapping of Working Memory Systems in Nonhuman Primates

PRINCIPAL INVESTIGATOR: Patricia Goldman-Rakic
Yale University
Department of Neuroanatomy
(203) 785-4689

R&T PROJECT CODE: 442k003 CONTRACT NO: N0001491J1251

Objective:
Proposed experiments will identify the neural substrates underlying spatial, form, and color working memory in behaving primates.

Approach:
Anatomical and behavioral techniques will be used to investigate the neural representation of different forms of visual and spatial working memory in the monkey brain. Monkeys will be trained to perform memory tasks while metabolic activity tracers will be marking relatively active neural substrates for subsequent anatomical analyses.

Progress:
System upgrades and significant programming adjustments were completed for complex image analysis. A successful double-label monkey experiment was completed that compared working memory and associative memory in the oculomotor paradigm. Auto radiographs are still being processed.

TITLE: Cognitive Neuroscience Analysis of Human Working Memory

PRINCIPAL INVESTIGATOR: John D.E. Gabrieli
Stanford University
Psychology Department
(415) 725-2430

R&T PROJECT CODE: 442k010 CONTRACT NO: N0001492J1184

Objective:
The objective is to fractionate human working memory into component cognitive processes needed to develop a detailed theory of the nature of general intelligence.

Approach:
General working memory abilities that have been linked to individual differences in general intelligence will be studied in normal subjects and carefully-selected subjects with well-localized brain injuries and specific cognitive impairments. Components are hypothesized to include 1) a declarative memory constituent dependent on medial-temporal lobe structures, 2) a general basal-ganglia dependent control system, and 3) a set of control subsystems critical to domain-specific processes within the frontal lobes.

Progress:
This grant is new in FY92.

TITLE: Functional Cortical Networks of Human Working Memory

PRINCIPAL INVESTIGATOR: Alan S. Gevins
EEG Systems Laboratory
(415) 957-1600

R&T PROJECT CODE: 442k005 CONTRACT NO: N0001491J1804

Objective:
Event-related brain potentials will be used to determine the specific neural substrates and temporal patterns of brain activity subserving putatively different working memory functions in normal human subjects.

Approach:
Distributed patterns of event-related brain potentials in normal human subjects will be recorded from multiple electrode sites during verbal and spatial working memory tasks and non-memory control conditions. Subsequent analyses, aided by anatomical data from magnetic resonance images, will provide 3-dimensional representations of sequential patterns of neural coactivation during perceptual, motoric, and cognitive components of the behavioral tasks.

Progress:
Novel spatial and verbal working memory tasks were developed and pilot studies are underway. Image clarification procedures were speeded up by a factor of 1000. Procedures for identification of primary auditory and somatosensory cortices were developed by combining steady-state evoked potentials and 3-dimensional megnetic resonance brain images.

Reports:
Gevins, A.S. et al. (1992). The future of high-resolution EEGs in assessing neurocognitive effects of mild head injury. Journal of Head Trauma Rehabilitation, 7 (2): 78-90.

Gevins, A.S., Le, J., Brickett, P., Reutter, B. and Desmond, J. (1991). Seeing through the skull: advanced EEGs use MIRs to accurately measure cortical activity from the scalp. Brain Topography, 4 (2): 125-131.

Gevins, A.S. and Illes, J. (1991). Neurocognitive networks of the human brain. In: Zappulla, R.A. (Ed.) Windows on the Brain: Neuropsychology's Technological Frontiers. New York Academy of Sciences: New York, 22-44.

TITLE: Integrating Cognitive and Biological Theories of Learning

PRINCIPAL INVESTIGATOR: Mark A. Gluck
Rutgers University
Center for Molecular & Behavioral Neuroscience
(201) 648-1080

R&T PROJECT CODE: 400x115 CONTRACT NO: N0001492J1623

Objective:
Computational constraints derived from neural evidence will be used to develop and refine a comprehensive network model of the computational processes underlying human learning and memory. The model will be used to make quantitative predictions of classification performance by normal and amnesic subjects and will be extended to account for a wider range of cognitive phenomena including categorization, pattern recognition, transitive inference, probabilistic judgements, and decision-making.

Approach:
Computer simulations of human cognitive processes based on animal learning and neural network theory will be developed and compared to the performance of normal and memory-impaired human subjects on a variety of pattern classification and related tasks. The PI's "configural-cue" and hippocampal neural network models will be compared to alternative connectionist models. Connectionist models will be applied to a Navy data base of sonar signals and evaluated as an automatic pattern classification scheme.

Progress:
A computational model of hippocampal function has been modified and applied to new data on the neural basis of transitive inference.

Reports:
Gluck, M.A. and Meyers, C.E. (1992). Hippocampal-system function in stimulus representation and generalization: a computational theory. Proc. 14th Ann. Mtg. of Cogn. Sci. Soc.

Gluck, M.A. and Granger, R. (1992). Computational models of the neural bases of learning and memory. Ann. Rev. Neurosci.

TITLE: Neurophysiological Components of Working Memory in Humans

PRINCIPAL INVESTIGATOR: Eric Halgren
Universite de Rennes I
Clinique Neurologique
33-99.28.41.32

R&T PROJECT CODE: 442k011 CONTRACT NO: N0001492J1742

Objective:
The proposed research will measure neural activity at distributed locations within the human brain during Navy-relevant working memory tasks in order to discern functional components underlying general intellectual and problem-solving skills and abilities.

Approach:
Subjects with multiple intracranial cortical and hippocampal depth electrodes implanted for clinical purposes will be tested on a variety of working memory tasks. Single- and multi-neuron recordings will be made while subjects perform memory tasks that vary memory load, processing time, sensory modality, and knowledge domain. The temporal and spatial pattern of neural activation will be evaluated for evidence of component processes.

Progress:
This grant is new in FY92.

TITLE: Working Memory Processes as Revealed by Positron Emission Tomography

PRINCIPAL INVESTIGATOR: John Jonides
University of Michigan
Department of Psychology
(313) 763-3272

R&T PROJECT CODE: 442k006 CONTRACT NO: N0001491J1713

Objective:
The intent of this project is to study the nature and localization of spatial working memory systems in the human brain through the use of positron emission tomography to monitor neural activity during well controlled working memory tasks.

Approach:
Neural activity and behavioral performance of normal human subjects on spatial working memory tasks will be measured with positron emission tomography. Perceptual non-memory control scans will be subtracted from brain scans obtained during memory tasks to obtain localization of spatial working memory substrates. Preliminary results will be extended and further experimental manipulations include delay interval, laterality of visual targets, task difficulty, and mental rotation.

Progress:
A promising new behavioral paradigm has been developed that isolates perceptual and mnemonic components of spatial working memory in humans. Preliminary results have been obtained that depict apparently robust neural activity in parietal and frontal lobes that reflect the cognitive demands and topography of spatial working memory.

TITLE: PET Studies of Components of High-Level Vision

PRINCIPAL INVESTIGATOR: Stephen M. Kosslyn
Harvard College
Department of Psychology
(617) 495-3932

R&T PROJECT CODE: 442k001 CONTRACT NO: N0001491J1243

Objective:
To determine which areas of the human brain are involved in the recognition and naming of visual objects and to test specific features of a cognitive model of high-level visual processes and attention.

Approach:
Differential cerebral blood flow in the normal human brain will be measured by positron emission tomography (PET) as a marker for neural metabolic activity associated with specific mental processes in visual object recognition and naming. Additive cognitive processes will be manipulated to test the dynamics of local cerebral blood flow and the assumption of independent cerebral processes in cognition.

Progress:
Mental imagery experiments demonstrated the same pattern of metabolic activation as that observed during a perceptual task. Specifically, mental imagery produced activation in primary visual cortices, areas 17 and 18 as defined by a computerized brain atlas. Additional activation was observed in areas associated with attentional mechanisms such as the thalamus, inferior parietal lobe, and the anterior cingulate gyrus. These results indicate a strong role of attentional processes in mental imagery.

TITLE: Instrumentation for Magnetic Resonance Studies of Cognitive Activity

PRINCIPAL INVESTIGATOR: Paul C. Lauterbur
University of Illinois
Department of Medical Information Sciences
(217) 333-2186

R&T PROJECT CODE: 442k008 CONTRACT NO: N0001492J1160

Objective:
The purpose of this project is to establish a laboratory facility for the study of the neural substrates of human behavior through magnetic resonance imaging and magnetic resonance spectroscopy.

Approach:
The budget contributes to the purchase of a 4 Tessla shielded magnet used in the development of a magnetic resonance laboratory facility. The large magnet allows improved spatial and temporal resolution over existing facilities. The relatively non-invasive technique does not require radioactive isotopes generated on-site as does positron emission tomography. Thus repeated testing of individual subjects can be obtained obviating the need to average data across subjects, eliminating the large variance seen in PET studies due to individual differences.

Progress:
This grant is new in FY92.

TITLE: Tracking the Biology of Dynamic Cognitive Processing in Working Memory and Skill Acquisition

PRINCIPAL INVESTIGATOR: Walter Schneider
University of Pittsburgh
Learning Research and Development Center
(412) 624-7061

R&T PROJECT CODE: 4422569 CONTRACT NO: N0001491J1708

Objective:
The purpose of this project is to identify and monitor serial and parallel component processes in the control of attention-shifting, working memory, and problem-solving using behavioral and neuro-imaging evidence.

Approach:
New techniques have been developed to control the rate of attention-shifting, the sensory modality and complexity of information processing, and memory load during the acquisition and performance of attention-shifting and problem-solving tasks. Neural activity will be monitored during performance of these tasks through a 64-channel scalp electrode recording system and state-of-the-art data analysis techniques. Opportunistic experiments will be carried out using functional magnetic resonance echo-planar imaging and intracranial depth electrode recording techniques.

Progress:
During a first year of funding, the PI purchased and assembled equipment to support a state-of-the-art electrophysiological scalp electrode recording facility modeled after the laboratory of the co-PI at Yale University Medical School. Preliminary experiments demonstrated the utility of new behavioral paradigms for event-related potential analysis and have provided evidence of endogenous activation of primary visual cortex in humans during attention-shifting tasks.

COGNITIVE SCIENCE

KNOWLEDGE, SKILL AND EXPERTISE

TITLE: Applying Statistical Methods to Machine Translation

PRINCIPAL INVESTIGATOR: Peter F. Brown
International Business Machines Corporation
T.J. Watson Research Center
(914) 784-6514

R&T PROJECT CODE: 4428033 CONTRACT NO: N0001491C0135

Objective:
The objective of this project is to develop a statistical approach to direct machine translation of one language to another.

Approach:
Statistical analyses will be performed on large corpora of texts in order to detect regularities which will enable the correct tagging of parts of speech within a single language and to detect word features which affect translation as well as to detect multiple word sequences which must be translated as a whole. A statistical model of the translation between English and French will be constructed and tested on its ability to translate short sentences.

Progress:
This contract is new in FY92.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Memory and Use of Examples in Problem Solving

PRINCIPAL INVESTIGATOR: Jeremiah M. Faries
Northwestern University
Psychology Department
(312) 491-0347

R&T PROJECT CODE: 442f012 CONTRACT NO: N0001491J1742

Objective:
The objective of this project is to study the way in which students draw upon instructional text, instructional example problems, and past problem solving experiences in order to solve new problems in the process of acquiring a problem solving skill. It is expected that this will provide insights into the way in which instruction for problem solving skill can be best designed.

Approach:
The BATBOOK computer environment will be used to observe and record the way in which students refer back to instructional materials and past problem solving experiences in the course of learning a problem solving skill. The nature of the instructional materials provided will be experimentally varied in order to determine the relative contributions of instructional text, instructional worked examples, and practice problem solving to the acquisition of problem solving skills. This project is part of a collaboration with Brian Reiser of Princeton University (442f010); Faries will do a large proportion of the empirical data collection, using the more diverse subject population available at Northwestern, as compared to Princeton.

Progress:
This new faculty member has established his laboratory and begun collecting data in the first series of experiments.

TITLE: Toward a Model of Expert Knowledge Structures and Their Role in Cognitive Task Performance

PRINCIPAL INVESTIGATOR: Richard J. Koubek
Purdue Research Foundation
Department of Industrial Engineering
(317) 494-5444

R&T PROJECT CODE: 4421558 CONTRACT NO: N0001492J1153

Objective:
This research is exploring differences in high-level cognitive skill based on individual differences in the knowledge representation of a complex cognitive domain. The main task is the development of a model of and a paradigm for externalizing the effect of an individual's acquired representation of domain knowledge on skilled performance. Additional studies will examine the implications of certain training variables and global cognitive abilities on the representation acquired.

Approach:
(a) An initial study involving students learning a word-processing task will explore the relationship between training variables, acquired representation, and performance as a function of task type. This study will also explore the feasibility and validity of an approach based on similarity judgments and multidimensional scaling for obtaining information about an individual's knowledge representation. (b) A second study will develop a taxonomy of expert knowledge representation types and will examine the suitability of each type for performing generic subtasks within a technical domain. In this study the efficacy of the similarity judgment-multidimensional scaling approach and an approach based on monitoring information requests during task performance to draw inferences about an individual's representation of domain knowledge will be compared. (c) A third study will examine the relationships between global cognitive abilities and features of an individual's acquired representation.

Progress:
Preliminary indices of aspects of knowledge representations have been developed. Empirical results indicate that measured aspects of knowledge representation significantly influence performance on both complex and simple repetitive tasks.

Report:
Koubek, R.J. & Mountjoy, D.N. (1991) The impact of knowledge representation on cognitive-oriented task performance. International Journal of Human Computer Interaction, 3, 31-37.

TITLE: WORDNET: A Lexical Database for English

PRINCIPAL INVESTIGATOR: George A. Miller
Princeton University
Cognitive Science Laboratory
(609) 258-5973

R&T PROJECT CODE: 4422566 CONTRACT NO: N0001491J1634

Objective:
The objective of this project is to extend WordNet, a semantic lexical resource for natural language computing, to incorporate contextually-based strategies for the disambiguation of word senses.

Approach:
WordNet represents the semantics of English as a network of relationships that are semantically important in human word knowledge--relationships of semantic similarity and opposition of meaning, superordinate and subordinate relations, and part-whole relationships, among others. In the present effort, large bodies of textual information will be processed to determine how context serves to differentiate the different meanings (senses) that the same superficial word form may have, and ways will be sought to effectively represent that contextual information within the network structure of WordNet.

Progress:
Versions 1.0 and 1.1 of WordNet have now been available by ftp (electronic file transfer) and are in the possession of a number of users. Persons interested in obtaining information about WordNet or WordNet itself may communicate with wordnet@clarity.princeton.edu. New research is focused on disambiguation of word meaning. Syntactically tagged text corpora have been obtained and work has begun on converting these to semantically tagged texts. An experiment to determine the feasibility of semantic disambiguation based on small amounts of surrounding context (2 words prior, 2 words following), has begun.

Report:
Miller, G.A. (Ed) (1990) Five Papers on WordNet, special issue of the International Journal of Lexicography, 3, 235-312.

Outside Funding:
This project is funded jointly by ONR and DARPA.

TITLE: System Dynamics and Computer Modeling Expertise

PRINCIPAL INVESTIGATOR: Mark Siegel
University of the District of Columbia
Department of Psychology
(202) 282-2152

R&T PROJECT CODE: 4422564 CONTRACT NO: N0001491J1360

Objective:
The project will identify key concepts in the systems dynamics approach to computer modeling of phenomena, will determine how those concepts are related in the understanding of experts in the field, and will determine how expertise develops during instruction.

Approach:
Publications on systems dynamics will be used to develop a candidate list of key concepts. Experts in the field will be consulted to review and possibly modify the list. Computerized presentations of pairs of concepts will be used to elicit judgements of relatedness from a group of expert subjects and these data will be analyzed using the Pathfinder program to infer underlying conceptual networks. Provided this initial research effort is successful, additional subject groups varying in expertise will be studied in the same manner.

Progress:
An advisory board of systems dynamics experts has been formed for the project. Software tools have been developed to permit the planned remote data collection effort from cooperating expert subjects in dispersed locations. These tools are being made available to the wider research community interested in the use of Pathfinder network analysis for cognitive diagnosis of knowledge structures.

TITLE: Memory and Use of Examples in Problem Solving

PRINCIPAL INVESTIGATOR: Brian J. Reiser
Princeton University
Psychology Department
(609) 258-6081

R&T PROJECT CODE: 442f010 CONTRACT NO: N0001491J1125

Objective:
This project aims to understand how students refer back to past instructional or personal problem solutions in order to solve new problems by processes of analogy.

Approach:
An innovative computerized instructional environment will be used to conduct a variety of experiments in which references to either text example problems or past problem solutions by the student can be tracked and recorded. The record of search attempts will also provide evidence concerning the way in which past experience with problem solving examples is coded in the student's memory. Various characteristics of the instructional example problems will be experimentally manipulated in order to explore the effect on example accessibility and utility.

Progress:
An initial experiment has shown, as predicted, that actually solving example problems--as opposed to merely studying them--enhances the likelihood of later retrieving and attempting to retrieve structurally similar problems. This contrasts with many experimental results in less realistic situations that show overwhelming reliance on superficial similarities.

Report:
Faries, J. M. (1991) Reasoning-based retrieval of analogies. Department of Psychology, Princeton University.

TITLE: A Case-Based Approach to Pianning

PRINCIPAL INVESTIGATOR: Colleen M. Seifert
University of Michigan
Psychology Department
(313) 763-0210

R&T PROJECT CODE: 442f009 CONTRACT NO: N0001491J1128

Objective:
The objective of this project is to answer a variety of questions about the functioning of human memory that arise in the course of building AI models of case-based reasoning, problem solving and decision-making: how the representation of information during initial learning affects the ability to retrieve and use it in new situations, how information that is retrieved depends upon the relation to pending goals in problem-solving activity, how prior cases are retrieved and used in decision-making and explanation.

Approach:
A variety of experimental paradigms appropriate to these questions are being used in the research, ranging from simple reports of reminding of past cases to the observation of actual use during an on-going decision-making or problem-solving tasks. The relation of features available at original learning to cues available at the time of retrieval is manipulated.

Progress:
One series of experiments explored the heavily cited but inconsistently replicated "Zeigarnik effect" that interrupted tasks are better recalled than completed ones. The nature of the task interruption, the time spent on problem solving -- whether complete or incomplete -- and the relative sizes of the sets of complete and incomplete tasks were all found to affect the result. A second series of experiments explored memory access to analogous cases with similarity at an abstract level, testing the hypothesis that features which would have predictive value in problem solving are favored in memory access. The hypothesis was confirmed.

Report:
Johnson, H.M. and Seifert, C.M. (in press) The Role of Predictive Features in Accessing Analogies, Journal of Memory and Language

COGNITIVE SCIENCE

LEARNING AND INSTRUCTION

TITLE: Predicting What People Learn from Examples

PRINCIPAL INVESTIGATOR: Richard Catrambone
Georgia Tech Research Corporation
Department of Psychology
(404) 894-2682

R&T PROJECT CODE: 4422561 CONTRACT NO: N0001491J1137

Objective:
This project aims to understand how problem solving examples can be designed to bring about the most efficient and effective learning of appropriately generalized problem solving skills.

Approach:
A production system analysis of the problem solving skills will be conducted in order to provide a systematic basis for the design of examples. Several hypotheses concerning the conditions which result in the learner identifying and recognizing the subgoals that organize problem solving performance will be tested in experiments which provide learners with appropriately designed example problems.

Progress:
A first series of experiments has been conducted.

TITLE: Computer Generation of Complex Tutorial Dialogues

PRINCIPAL INVESTIGATOR: Martha Evens
Illinois Institute of Technology
Department of Computer Sciences
(312) 567-5153

R&T PROJECT CODE: 4422554 CONTRACT NO: N0001489J1952

Objective:
The objective of this grant is to learn how to produce intelligent computer-generated tutorial dialogue.

Approach:
The tutorial guidance provided by expert human tutors working with students using an instructional simulation will be recorded and analyzed. The approach to generating text will be similar to that taken by the AI group at U. Mass Amherst--McKeown, McDonald, and Woolf--but the Lexical Functional grammar of Kaplan and Bresnan will be used with lexical selection based on Even's previous lexical work. In addition, information taken from the student model of the tutoring system will be used to individualize the tutorial dialogue appropriately for student needs.

Progress:
Both face-to-face and keyboard-to-keyboard human tutoring sessions have been recorded and analyzed, a computer program having been developed for managing and recording the latter. Debriefing sessions have been used to extract both tutoring rules and student modeling rules from the expert tutors participating in the project, who were found to differ significantly. It was found that tutors plan their discourse in much larger chunks than is usual for current artificial language generation. A limited language generation capability that adapts to several features of the current situation has been developed, as has capability to process imperfect input from students.

Report:
Woo, C., Evens, M. (1991). Dynamic planning in an intelligent cardiovascular tutoring system. Proc. Fourth Annual IEEE Symposium on Computer Based Medical Systems, Baltimore, May, 1991, p. 226-233.

TITLE: Analogical Processes and Learning in Physical Domains

PRINCIPAL INVESTIGATOR: Dedre Gentner
Northwestern University
Department of Psychology
(312) 467-1272

R&T PROJECT CODE: 4422573 CONTRACT NO: N0001492J1098

Objective:
The goal is to construct and test a general theory of analogical thinking as it occurs in both learning and reasoning. Parametric investigations of the detailed assumptions of the formal model of this theory, the Structure Mapping Engine, will be conducted in order to more precisely specify detailed aspects of the theory. More aspects of the application of the theory will be automated in order to increase its objectivity, and its application to the new and more complex domain of the learning of causal models will be explored.

Approach:
Psychological and computational experiments will be conducted in parallel to determine what computational theory can best account for human data on learning, analogy formation, and analogy evaluation. The learning of causal models for physical phenomena in artificial worlds will be an important aspect of the psychological investigations.

Progress:
Simulation models of both memory retrieval (MAC/FAC for "many are called, but few are chosen) and of analogical mapping (SME -- the structure mapping engine) have been developed and proved capable of accounting for the results of many experiments.

Report:
Gentner, D. & Forbus, K. (1991) MAC/FAC: A model of similarity-based retrieval, Proceedings of the Cognitive Science Society.

TITLE: Questioning Mechanisms during Tutoring, Conversation, and Human-Computer Interaction.

PRINCIPAL INVESTIGATOR: Arthur C. Graesser
Memphis State University
Department of Psychology
(901) 678-2742

R&T PROJECT CODE: 4422576 CONTRACT NO:

Objective:
The objective of this project is to understand and computationally model the processes of question asking and answering in tutorial dialogues.

Approach:
Under a previous grant, human tutorial dialogues were recorded under controlled conditions and then transcribed. Questions and answers were classified according to a theoretical framework developed in Graesser's previous work. Under the current grant, more in-depth analyses will be conducted, focusing on higher-level phenomena such as the pedagogical strategies of tutors and the collaborative processes between student and tutor. Three computational models for the sequences of speech acts will be comparatively tested: a recurrent connectionist network, a recursive transition network, and a production system.

Progress:
It was found that the rate of student questions in tutorial sessions is approximately 100 times as great as in conventional classrooms. Approximately 20-25% of the questions asked by both students and tutors are of a relatively deep nature (ie. why? why not? how? what if?). Such questions rarely occur in regular classrooms. The questions and answers of both students and teachers tended to be vague and poorly specified, however. It was found that tutors rarely give negative feedback, even to answers that are clearly incorrect. Positive feedback is somewhat less infrequent in response to incorrect answers. Data from two different tutorial situations--college students being tutored in research design and school children being tutored in math--were remarkably similar, suggesting generality of the results. As a spinoff, a theory-based "point and query" computer interface was developed and tested in an instructional application.

Report:
Graesser, A.C. (1992). Questioning mechanisms during complex lerning. Department of Psychology, Memphis State University.

TITLE: Computer Generation of Complex Tutorial Dialogues

PRINCIPAL INVESTIGATOR: Joel A. Michael
Rush Presbyterian
Department of Physiology
(312) 942-6426

R&T PROJECT CODE: 442f011 CONTRACT NO: N0001491J1622

Objective:
The objective of this grant is to learn how to produce intelligent computer-generated tutorial dialogue.

Approach:
The tutorial guidance provided by expert human tutors working with students using an instructional simulation will be recorded and analyzed. The approach to generating text will be similar to that taken by the AI group at U. Mass Amherst--McKeown, McDonald, and Woolf--but the Lexical Functional grammar of Kaplan and Bresnan will be used with lexical selection based on Even's previous lexical work. In addition, information taken from the student model of the tutoring system will be used to individualize the tutorial dialogue appropriately for student needs.

Progress:
Tutorial data have been collected and analyzed for both face-to-face and keyboard-to-keyboard interaction. Arrangements have been made for the study of a wider variety of expert medical faculty doing tutoring with the CIRCSIM simulation. See the coordinated Evens grant for further information and related progress.

Report:
Seu, J., Chang, R-C., Li, J., Evens, M., Michael, J., & Rovick, A. (1991) Language differences in face-to-face and keyboard-to-keyboard tutoring sessions. Proceedings of the Cognitive Science Society, Hillsdale, NJ: Erlbaum.

TITLE: Explanatory Dialogues in a Complex Real World Domain

PRINCIPAL INVESTIGATOR: Johanna Moore
University of Pittsburgh
Learning Research and Development Center
(412) 624-7050

R&T PROJECT CODE: 4422571 CONTRACT NO: N0001491J1694

Objective:
This project aims to develop the capability to conduct an explanatory dialogue with a trainee learning how to diagnose faults in a complex electronic device.

Approach:
Within the context of an existing maintenance tutor, data will be collected on the way that a human expert responds to trainee questions and provides explanations. Artificial intelligence techniques will be used to emulate this performance. Discourse goals will be identified and the system's information about the situation will be appropriately selected, abstracted and summarized in order to generate a response that meets the standards of human discourse.

Progress:
Much of the effort to date has gone into implementing the Sherlock Tutor and the previously developed language generation programs and grammars on a single computer, as required for this study. Recording of problem solving sessions with a human tutor providing the explanations that are to be emulated has begun. A master's degree project focused on the use of discourse markers in explanatory texts has been initiated; these markers help readers understand the intended semantic structure of the text and this work will contribute to the quality of explanations generated in this project.

TITLE: Cognitive Function of Theoretical Knowledge in Procedural Learning

PRINCIPAL INVESTIGATOR: Stellan Ohlsson
University of Pittsburgh
Learning Research and Development Center
(412) 624-7020

R&T PROJECT CODE: 442f008 CONTRACT NO: N0001489J1681

Objective:
The objective is to understand how knowledge of principles in a domain can be used to aid learning and adaptive modification of problem-solving procedures.

Approach:
Computer simulations of arithmetic and physics problem-solving will be built to determine how principled knowledge can be used to monitor, acquire, and adapt procedures. Learning mechanisms proposed in important cognitive theories of learning, chunking (Newell), knowledge compilation (Anderson) and explanation-based learning (DeJong), will be compared for their impact on overall learning performance.

Progress:
A model of a routine scientific skill, the construction of Lewis structures for organic molecules, was developed. A mathematical model of the learning process has been formulated and an exponential learning equation was derived analytically.

Reports:
Ohlsson, S., & Rees, E. (in press) Adaptive search through constraint violations. Journal of Experimental and Theoretical Artificial Intelligence.

Ohlsson, S., & Rees, E. (in press) The function of conceptual understanding in the learning of arithmetic procedures. Cognition and Instruction.

Ohlsson, S. (1990) Comparative evaluation of knowledge-based simulation models of procedural learning. Technical Report No. KUL-90-03. Pittsburgh, PA: University of Pittsburgh.

TITLE: A Model of Long-Term Learning: Integration of Knowledge Acquisition and Knowledge Compilation

PRINCIPAL INVESTIGATOR: Kurt VanLehn
University of Pittsburgh
Computer Science Department
(412) 624-7458

R&T PROJECT CODE: 4422577 CONTRACT NO:

Objective:
The objective of the present grant is to extend the CASCADE model of the acquisition of problem solving skill to incorporate processes of knowledge compilation or consolidation and to include a more realistic model of memory access for previously learned information. In addition, the resulting model will be evaluated against 30 major generalizations about learning that are found in the literature.

Approach:
Once the CASCADE model has been extended, simulated human learning will be used to generate predictions that can be compared to major findings about learning in the research literature--the form of learning curves, the nature of transfer, and so on.

Progress:
In the previous grant, the CASCADE model was highly successful in modeling human protocol data on the learning of physics problem solving skill. Most behavior was accounted for by problem-solving of the Newell & Simon type. The analogical learning mechanisms previously proposed by John Anderson also played a significant role, but VanLehn also found evidence for a novel learning mechanism that generates new candidate rules when an impasse is encountered. Simulations provided a theory-based explanation for major observations in the study of human learning of physics--the value of self-explanation of steps in example problems (which proved to be the source of much actual learning of new rules used in problem solving) and the surprising fact that more successful learners are more likely to complain of failures to understand (because they encounter impasses when trying to explain problem solving steps).

Report:
VanLehn, K. & Jones, R.M. (in press) Learning by explaining examples to oneself: A computational model. In A. Meyrowitz & S. Chipman (Eds.) Cognitive Models of Complex Learning. Boston: Kluwer Academic.

TITLE: A Consortium for Lexical Research

PRINCIPAL INVESTIGATOR: Yorick Wilks
New Mexico State University
Computing Research Laboratory
(505) 646-5466

R&T PROJECT CODE: 4428029 CONTRACT NO: N0001491J1440

Objective:
This project aims to provide lexical resources for natural language computing and to make those resources available to the computational linguistics research community.

Approach:
Lexical resources will be sought from members of the computational linguistics community. These will include word lists, dictionaries, statistical data, etc., as well as tools for the analysis of lexical and text data. These resources will be included in a computerized repository and will be made available to members of the computational linguistics research community, under the licensing agreements required by the contributors of the information. A theory-neutral format for the representation of lexical data will be sought.

Progress:
Establishment of the consortium has been widely announced to the interested research communities, and the collection of lexical resources has begun. A workshop to discuss issues relevant to the operation of the consortium has been planned for the Winter of 1992.

Outside Funding:
Funds for this project are provided by DARPA.

COGNITIVE SCIENCE

MODEL-BASED MEASUREMENT AND COGNITIVE DIAGNOSIS

TITLE: Conditional Dependence

PRINCIPAL INVESTIGATOR: Robert D. Gibbons
University of Illinois at Chicago
Department of Psychiatry
(312) 413-1357

R&T PROJECT CODE: 4421553 CONTRACT NO: N0001489J1104

Objective:
A previously developed approximation technique to obtain estimates of pattern probabilities that are robust to violations of conditional independence will be extended to new contexts including modelling performance on long tests (perhaps 50 items in length), on adaptive tests, on tests scored polychotomously, and on tests composed of several homogeneous subtests.

Approach:
Several techniques for estimating the residual covariances will be studied: (a) using the sample tetrachoric correlations, (b) using the expected covariances from a higher dimensional solution, and (c) fitting specific patterned structures (e.g., first-order autocorrelation, block-diagonal, etc.). The viability of these approaches will be studied using simulated and real test data. These methods are applied to both ability and item parameter estimation.

Progress:
Preliminary work has focused on developing an EM solution and on implementing a ridge-like adjustment to stabilize a final Newton-Raphson step. An important bi-product of this work is the identification of a series of "special cases" in which traditional Gaussian quadrature approximations can be used. These special cases have already led to several applications where no statistically rigorous solutions were previously available.

Report:
Gibbons R.D., Hedeker D.R. & Bock R.D. (1991) Full information item bi-factor analysis. Psychometrica, in press.

TITLE: Structural Assessment of Knowledge and Skill

PRINCIPAL INVESTIGATOR: Timothy E. Goldsmith
University of New Mexico
Department of Psychology
(505) 277-7505

R&T PROJECT CODE: 4421564 CONTRACT NO: N0001491J1368

Objective:
A substantial body of work has established that distinguishing properties of expert knowledge are structural. The objective of this work is to explore procedures for empirically obtaining and formally representing and comparing structural aspects of an individual's domain knowledge.

Approach:
In previous work the PI's developed and evaluated techniques based on the direct assessment of the relatedness of domain concepts and the scaling of those data using the PathFinder algorithm. This project will extend the previous work in several directions. First, it will explore alternatives to direct assessment of relatedness. Second, it will explore alternative definitions of idealized experts. Third, it will explore alternative measures of structural aspects and of quantifying structural similarity. Finally, it will explore alternative definitions of expertise.

Progress:
Initial work has focused on analysis of methods for evaluating structural relations. The purpose of these methods is to determine how similar one set of concept relations (e.g., from a student) is to another set (e.g., from an instructor). Investigators have developed a taxonomy of methods for assessing such similarity. In other work investigators have obtained results which characterize features of the sampling distribution of C, a particular index of similarity.

Report:
Goldsmith, T.E., Johnson, P.J., and Acton, W.H. (1991). Assessing Structural Knowledge. Journal of Educational Psychology, 83, 88-96.

TITLE: Structural Robustness and Local Dependence in Item Response Theory

PRINCIPAL INVESTIGATOR: Brian Junker
Carnegie-Mellon University
Department of Statistics
(412) 268-2717

R&T PROJECT CODE: 4421560 CONTRACT NO: N0001491J1208

Objective:
This project seeks to extend Stout's essential independence framework in several directions. First, it seeks more complete trait-estimation and trait-distribution-estimation theories for tests which are only essentially unidimensional. Second, it seeks an item-response-function estimation theory. Third, it seeks necessary and sufficient conditions on observables for a test to be strictly unidimensional. Fourth, it will explore the theoretical relationships between classes of local dependence structures and multidimensionality.

Approach:
Initial work will (a) explore generalizations of the Kalback-Leibler information distance function as a vehicle for studying the optimality of item response functions in an essential-independence framework; (b) explore the theoretical connections between Sympson's polyweighting and efficient estimation of the dominant trait for essentially unidimensional tests; and, (c) empirically explore a novel approach to trait distribution estimation and compare it with extant procedures (especially Mislevy's).

Progress:
(a) Established the consistency of the "maximum likelihood" estimator of ability computed using a conditionally-independent likelihood function, when only essential independence holds, as test length increases. This robustness does not extend to the variance of this wrong-model MLE. (b) Established that the optimal choice for factors in the independence likelihood are the marginal densities for the item response, given the trait. (c) Established conditions under which the wrong model posterior distribution of the latent trait is asymptotically Normal centered at the wrong-model MLE and scaled by the wrong-model empirical Fisher information.

Report:
Clarke, B. S. & Junker, B. J. (1991) Inference from the product of marginals of a dependent likelihood. (Tech. Rep. 508) Pittsburgh, PA: Carnegie-Mellon University, Department of Statistics.

TITLE: New Tools for New Tests

PRINCIPAL INVESTIGATOR: Michael V. Levine
University of Illinois
Department of Educational Psychology
(217) 333-2186

R&T PROJECT CODE: 4421562 CONTRACT NO: N0001490J1958

Objective:
Two general approaches for modelling performance on complex cognitive tasks are being developed: maximum-likelihood (MFS) and algebraic (AFS) formula-score theories. MFS will be a tool for checking hypotheses about information processing on complex tasks. Abstract manifolds from AFS will be a vehicle for obtaining representations of performance. Computer algorithms for both approaches are being refined.

Approach:
A variety of constraints suggested by cognitive process models in specific task domains are being explored to reduce the estimation space of item response functions. These include smoothness constraints, monotonicity constraints, and explicit functional form constraints in task domains with sufficiently strong psychological theory. Initial work on AFS will explore low-dimensional parameterizations of test manifolds, improvements to numerical algorithms, and exploration of the viability of the AFS approach for specific modelling applications.

Progress:
(a) Special properties of test manifolds arising from cylindrical models have been identified which make it possible to test whether cylindrical models are a reasonable representation. (b) Efficient algorithms for solving the functional equations for two-dimensional cylindrical models have been developed. (c) Empirical studies have demonstrated that nonparametric approaches can recover unidimensional item-response functions as well as parametric approaches based on logistic assumptions, even when response data were generated by logistic models.

TITLE: Multidimensional Item Response Theory Applied to Practical Testing Problems

PRINCIPAL INVESTIGATOR: Mark D. Reckase
American College Testing Program
Test Development Division
(319) 337-1105

R&T PROJECT CODE: 4421556 CONTRACT NO: N0001489J1908

Objective:
Develop a practical methodology for analyzing test items that require more than one cognitive ability to achieve a correct response. Issues under study include: (a) estimating item parameters, (b) linking the scales of item parameter estimates from different analyses, (c) equating scales of vector ability parameter estimates and of composites of elements of the ability vectors, (d) technical specification for tests that measure multiple abilities, and (e) multidimensional adaptive testing.

Approach:
(a) Estimates of standard errors and of statistical bias will be used to determine the optimal characteristics of samples used to obtain item parameter estimates. (b) Marginal maximum likelihood procedures will be evaluated for parameter estimation. (c) The Stocking and Lord procedure will be explored as a model for linking the scales of parameter estimates. (d) Equating methodologies will be evaluated with empirical studies on ACT Assessment data.

Progress:
Methods have been developed to gauge the parallelism of tests that measure multiple cognitive dimensions. (b) New procedures have been developed to assess the reliability of tests that measure multiple dimensions.

Report:
Spray, J., Davey, T.C., Reckase, M.D., Ackerman, T., & Carlson, J.E. (1990). Comparison of two logistic multidimensional item response theory models. (Research Report ONR 90-8) Iowa City, IA: American College Testing Programs.

TITLE: Further Advancement of Latent Trait Theory and Challenge to the Multiphase Response

PRINCIPAL INVESTIGATOR: Fumiko Samejima
The University of Tennessee
Department of Psychology
(615) 974-6846

R&T PROJECT CODE: 4421549 CONTRACT NO: N0001490J1456

Objective:
The objective of this work is to extend the theoretical foundations of latent-trait theory. This includes: (a) improvements to modelling techniques, (b) the development of a framework for studying the validity of items and tests as a function of ability, (c) the development of efficient multidimensional modelling techniques, and (d) the extension of latent-trait theory to modelling the details of performance on tasks involving sequences of behavior.

Approach:
(a) The PI's Differential Weight Procedure will be refined and tested. (b) The usefulness of approximations derived from results for multidimensional models of continuous responses will be examined. (c) A variety of ways to conceptualize an item's (and a test's) local validity will be examined. And, (d) applications to modeling a student's understanding of digital circuits will be explored.

Progress:
(a) A new approach for modeling the response characteristics of discrete response data has been developed (i.e., the differential weight procedure). This procedure appears to be a substantial improvement over the familiar simple-sum procedure. (b) Initial measures of item and test validity which are population-free and locally defined have been developed. (c) smoothing simple-sum estimates using 4-parameter logistic models has been shown to improve estimates. (d) Two modified test information functions have been developed.

Report:
Samejima, F. (1990) Modifications of the test information function. (Tech. Rep.) Knoxville, TN: University of Tennessee, Department of Psychology.

TITLE: Foundations of Multidimensional Item-Response Theory.

PRINCIPAL INVESTIGATOR: William F. Stout
University of Illinois
Department of Statistics
(217) 333-6218

R&T PROJECT CODE: 4421548 CONTRACT NO: N0001490J1940

Objective:
This work is further developing the foundations of item response theory for multidimensional data sets. This includes: (a) exploration of the theoretical relationship between a conditional-association notion of dimensionality and Stout's notion of the essential dimensionality of a data set, (b) exploration of the implications of the Suppes and Zanotti Common Causes Theorem for multidimensional IRT modelling, (c) development of a framework for studying issues of test bias based upon the notion of the essential dimensionality of a test, and (d) exploration of alternative dependence structures for multidimensional modelling.

Approach:
(a) Stout's notion of the essential dimensionality of a data set is being refined and extended, and the relationship between it and Holland's notion of conditional association is being studied. (b) The notion of test bias is being cast within the essential dimensionality framework in order to gauge when group differences are likely to be troublesome. (c) New notions of the reliability of a test are being explored. And, (d) models based upon sequential dependence structures are being examined.

Progress:
(a) A theoretical index of test bias and a statistical estimator of this index have been developed. (b) A methodology to explore and understand the test bias resulting from various 2-population IRT models has been developed. (c) A simulation study demonstrates the effectiveness of the Shealy-Stout procedure for detecting simultaneous item bias. (d) A theoretical index of the amount of essential multidimensionality and a statistical estimator of this index have been developed.

Report:
Stout, W. (1990) A new item response theory modeling approach with applications to unidimensional ability estimation. Psychometrika, 55.

TITLE: The Implications of Multidimensionality for Item Response Theory Applications

PRINCIPAL INVESTIGATOR: Ming-mei Wang
Educational Testing Service
Research Department
(609) 734-1933

R&T PROJECT CODE: 4421561 CONTRACT NO: N0001490J1970

Objective:
This work has three main objectives: (a) to examine the relationship between estimated multidimensional models and their estimated unidimensional counterparts; (b) to develop methods for empirically assessing the "strength" of multidimensionality in terms of the conditional dependence among items; and (c) to provide a framework for evaluating the effectiveness of unidimensional versus multidimensional modelling in testing applications.

Approach:
(a) A detailed analysis of the model-based explanations for differential item functioning is being constructed with emphasis on the issue of multidimensionality. (b) The effects of multidimensionality on test equating and on the interpretability of equated scores are being addressed in terms of characteristics of equating samples. (c) The relationship between characteristics of a multidimensional item pool and the efficiency of unidimensional adaptive testing is being studied. And, (d) an effective item selection strategy is being developed with the aid of estimated multidimensional item response functions.

Progress:
An analytic framework based on the linearity of item logic scores for the usual compensatory item response model was defined. Within this framework, algebraic relationships between unidimensional estimates and true multidimensional parameters were derived. The implications of this relationship for various testing applications have been explored.

Report:
Wang, M.M (1990) Unidimensional vs. multidimensional modeling for test development. (Tech. Rep.) Iowa City, IA: University of Iowa, Lindquist Center for Measurement.

TITLE: Advancement of the Theory of IRT-based Error Diagnostic Testing

PRINCIPAL INVESTIGATOR: Kikumi K. Tatsuoka
Educational Testing Service
Model-based Measurement Research Group
(609) 734-5424

R&T PROJECT CODE: 4421559 CONTRACT NO: N0001490J1307

Objective:
The objective of this work is to extend the Rule Space approach to diagnostic testing in three important areas: (a) a coherent approach to test item construction/selection/evaluation will be developed; (b) a more powerful approach to classifying response patterns will be sought; and (c) techniques for modelling "bug migrations" will be explored.

Approach:
(a) The investigators' approach to the item construction/selection issue involves constructing stochastic models of item subtask performance. Their initial approach views item subtasks as know entities. (b) The focus of attention for increasing the power of classification procedures will be on methods which avoid the multivariate Normality assumption employed in discriminant analysis. Methods such as kernel density estimation and the k-nearest-neighbor method will be explored initially. (c) Work on identifying and modelling "bug migrations" will employ combinatorial analyses of response patterns to detect phase changes.

Progress:
A detailed empirical validation of rule-space diagnoses in the fraction arithmetic domain has been completed. Results indicated that rule space is an effective tool for routing students to remedial instruction. (b) Results of a second study confirmed the robustness of the rule-space classification scheme to violations of the Normality assumption. (c) Developed a procedure for selecting the best set of items from a large item pool.

Report:
Tatsuoka, K. (1991) Item construction and psychometric models appropriate for constructed responses. (Research Report) Princeton, NJ: Educational Testing Service.

TITLE: Assessing Competence in Electronic Troubleshooting

PRINCIPAL INVESTIGATOR: Gautam Biswas
Vanderbilt University
Department of Computer Science
(615) 343-6204

R&T PROJECT CODE: 4421571 CONTRACT NO: N0001491J1680

Objective:
The objective of this project is to develop an approach to assessment that incorporates (a) student models of concepts and procedures, (b) changes in those models as expertise develops, and (c) theories about different forms of expert performance. This methodology will be validated for expertise in digital electronics.

Approach:
(a) Computational models which simulate troubleshooting performance as a function of troubleshooting strategies and mental models of digital circuit topology, function, and behavior will be constructed. These models will simulate both quantitative and qualitative aspects of problem solving. (b) Machine learning techniques will be employed to generate "buggy" models. And, (c) plan recognition techniques will be employed for model inference.

Progress:
Initial work has focused on (a) defining and characterizing the nature of the problem-solving domain and the tasks that students perform in this domain; (b) developing a set of computer-based tools that students will use in performing the tasks; and (c) identifying characteristic problems and setting up protocol analysis schemes. The domain has been extended to include topological issues in circuit design. The problem solving task has been extended to include design problems and troubleshooting in the context of circuit design. Tool design is focused on modifying existing tools to provide traces of student behaviors during problem solving.

TITLE: Knowledge Structure & Cognitive Diagnosis

PRINCIPAL INVESTIGATOR: Albert Corbett
Carnegie-Mellon University
Department of Psychology
(412) 268-2815

R&T PROJECT CODE: 4421570 CONTRACT NO: N0001491J1597

Objective:
There are four objectives in this project, each directed at increasing our understanding of individual differences in skill acquisition: (a) to explore the usefulness of a variety of improvements to the knowledge tracing mechanism in the LISP Tutor; (b) to evaluate the hypothesis that knowledge tracing is not sensitive to important qualitative differences in the student's understanding of the domain; (c) to implement a revised tutor interface that makes it possible to observe planning processes more directly; and (d) to explore the relationship between subskills in programming.

Approach:
(a) An augmented knowledge tracing mechanism will be constructed and evaluated. This augmentation will track the surface contexts within which productions are fired. (b) Individual differences in retention will be explored by varying the intervals between a production's firing after criterion has been reached. The effects of this manipulation on firing time and accuracy will be examined. (c) The frequency, timing and access strategy of example references will be related to postest performance. (d) A revised tutor interface which admits variation in coding order and object size will be implemented. The relationship between coding order, object size, memory for examples, and posttest performance will be examined. This will permit the study of the transition from forward to backward chaining. (e) Transfer effects between code generation and code evaluation for specific algorithms will be studied.

Progress:
Initial work has focused on extracting performance measures from the protocol files collected with the tutor in several experiments. The predictive relationship between these measures and posttest performance is being assessed along with the predictive strength of the tutor's explicit student model. Analyses indicate that relaxing the tutor's control over students' behavior in practice modifies relationships among the coding, evaluation and debugging skills students acquire.

TITLE: Fitting Symbolic Parameter Cognitive Models

PRINCIPAL INVESTIGATOR: Allen Newell
Carnegie-Mellon University
School of Computer Science
(412) 268-2602

R&T PROJECT CODE: 4421567 CONTRACT NO: N0001491J1527

Objective:
Many of the cognitive models in psychology can be viewed as subject-general models with parameters that take discrete symbolic values. Assigning values to the parameters creates a runnable model that simulates the subjects performance to some degree of accuracy. The objective of this project is to create a computational and statistical technology for fitting symbolically parameterized cognitive models to human data and for doing the analyses of these models for significance and sensitivity.

Approach:
The cornerstone of this project is the ASPM algorithm which identifies the sets of parameter values which fit the largest number of responses in an examinee's data set. In this project, ASPM will be refined, extended and evaluated.

Progress:
Initial work has focused on developing a C version of ASPM to replace the original LISP version and on studying the implications of certain data structure design issues. The new C version runs 10 to 35 times faster; the speed-up increases with the size of the task.

Report:
Polk, T., Newell, A., and VanLehn, K. (1992). Analysis of symbolic parameter models: a new technique for fitting models in cognitive science. School of Computer Science, Carnegie Mellon University.

TITLE: Fitting Symbolic Parameter Cognitive Models

PRINCIPAL INVESTIGATOR: Kurt VanLehn
University of Pittsburgh
Learning Research and Development Center
(412) 624-8414

R&T PROJECT CODE: 4421568 CONTRACT NO: N0001491J1529

Objective:
Many of the cognitive models in Psychology can be viewed as subject-general models with parameters that take discrete symbolic values. Assigning values to the parameters creates a runnable model that simulates the subjects performance to some degree of accuracy. The objective of this project is to create a computational and statistical technology for fitting symbolically parameterized cognitive models to human data and for doing the analyses of these models for significance and sensitivity. This is a small award coordinated with the primary grant to Newell.

Approach:
The cornerstone of this project is the ASPM algorithm which identifies the sets of parameter values which fit the largest number of responses in an examinee's data set. In this project, ASPM will be refined, extended and evaluated.

Progress:
Initial work has focused on developing a C version of ASPM to replace the original LISP version and on studying the implications of certain data structure design issues. The new C version runs 10 to 35 times faster; the speed-up increases with the size of the task.

TITLE: On-Line Assessment of Individual Expertise

PRINCIPAL INVESTIGATOR: Kurt VanLehn
University of Pittsburgh
Learning Research & Development Center
(412) 268-2781

R&T PROJECT CODE: 4421566 CONTRACT NO: N0001491J1532

Objective:
This work is exploring innovative methodologies for monitoring a student's evolving understanding of concepts and problem-solving skill in Physics. The idea is to develop a methodology for constructing theoretically well-grounded models of a student on the basis of data collected on line as the student is engaged in studying examples, solving quantitative and qualitative problems, planning a basic approach to a problem, and classifying problems.

Approach:
(a) A schema-based model of performance in Physics is being extended and refined. (b) The viability of novel indicators of schema attainment is being examined. Many of these data sources are suggested by laboratory experiments exhibiting performance differences as a function of expertise; others are suggested by experiments identifying learning skills which distinguish good and poor physics students. (c) A computational model of the acquisition of Physics skill is being refined. (d) Standard data analysis techniques are being supplemented by techniques from the AI and machine-learning literatures. In particular, techniques for plan recognition are being extended.

Progress:
Initial work has focused on developing the student interface and the physics problem editor for the testing system. Using a graphics environment called "CLIM", investigators are developing an editor which allows a user to enter physics derivations and draw force diagrams.

TITLE: Strategies of Skill Acquisition: A Mixture Model Approach to Measurement in the Context of Intelligent Tutoring

PRINCIPAL INVESTIGATOR: Mark R. Wilson
University of California, Berkeley
School of Education
(415) 642-7966

R&T PROJECT CODE: 4421569 CONTRACT NO: N0001491J1523

Objective:
The objective of this project is to explore techniques for drawing inferences about a student's study strategies and his/her understanding of a domain in the context of intelligent tutoring. Three task domains and tutors are under study: the LISP tutor (LISP programming language), the Bridge tutor (PASCAL programming language), and the Smithtown tutor (discovery of economic principles).

Approach:
Initial work is focusing on refining mixture models as a vehicle for drawing inferences about a student's learning and problem-solving strategies. In this phase, secondary analyses of existing data sets are being employed. Subsequent work will involve refinement of aspects of the cognitive models of domain knowledge, the collection of supplementary data (e.g., on a student's approach to example studying), on the exploration of inference network techniques for reaching conclusions about a student's domain knowledge, and on validation of the model-inference techniques.

Progress:
Using the CMU LISP tutor student model as an example, investigators have started sketching an alternative method of diagnosis using probabilistic inference networks. The focus has been on identifying better ways of using available measures, exploring the viability and usefulness of additional measures, and incorporating information on individual differences in experience and aptitude.

PERCEPTUAL SCIENCE

VISION AND VISUAL ATTENTION

TITLE: The Neural Basis of Visual Segmentation and Recognition

PRINCIPAL INVESTIGATOR: Gordon Baylis
University of California, San Diego
Department of Psychology
(619) 534-3000

R&T PROJECT CODE: 4424269 CONTRACT NO: N0001491J1735

Objective:
(1) Perform psychophysical and single unit studies to gain a deeper understanding of mechanisms underlying: the extraction of edges from multiple cues; how conflicting information is dealt with; how edges are classified as extrinsic and intrinsic; and how the description of extrinsic edges interacts with object segmentation. (2) Carry out psychophysical and physiological studies of the mechanisms and algorithms underlying the extraction of information on the third dimension. (3) Develop neural network models of object segmentation and recognition based on experimental evidence. Attempt to develop insights into the computational significance of the architecture of the inferior temporal cortex by analysis of model architectures.

Approach:
Techniques of psychophysics, modeling, and single unit recording in areas V4 and IT will be closely linked to produce biologically feasible models of object segmentation and three dimensional object recognition in primate visual system.

Progress:
A study of hierarchical position encoding shows that people appear to use an object-based or hierarchical position encoding system similar in operation to the well-known computational algorithm of R. Watt. A single unit recording study has been initiated which explores the effects of conflicting depth cues in the monkey visual cortex.

Report:
Baylis, G.C. & Driver, J. (In Press) Visual attention and objects: evidence for hierarchical coding of location. Journal of Experimental Psychology: Human Perception and Psychophysics, 1991.

TITLE: Studies of Contour and Surface Segmentation in Monkey Striate Cortex Using Voltage Sensitive Dyes

PRINCIPAL INVESTIGATOR: Gary G. Blasdel
Harvard College
Department of Neurobiology
(617) 732-1214

R&T PROJECT CODE: 442g005 CONTRACT NO: N0001489J1953

Objective:
The objectives of this research are to: (1) determine the extent to which striate cortex neurons are sensitive to the distinction between contour edges and surface edges; (2) to explore the anatomical and topological organization of striate cortex cell groups categorized on this basis.

Approach:
Extracellular single unit recordings in monkey striate cortex will be used to determine response selectivity to surface and contour edges in response to a variety of visual stimuli. Optical imaging with voltage-sensitive dyes will be used to map patterns of cortical activity in response to visual stimuli optimized for distinguishing contour-edge and surface-edge sensitive regions.

Progress:
Several findings have been obtained during the past year: (1) detailed analysis of the orientation maps of neurons in primate visual cortex revealed two predominant organizations: orientation preferences are either grouped into straight, parallel slabs, or they are organized around singularities; (2) the parallel slabs always dominate the singularities; and (3) these relationships support the idea that parallel slab structures of orientation preference engage in Hough-like extractions of single contours from visual noise, and that regions around singularities carry out surface texture analysis.

Report:
Blasdel, G. (In Press) Orientation selectivity, preference, and continuity in monkey striate cortex. Journal of Neuroscience, 1991.

TITLE: Visual Perception of Depth-from-Occlusion: A Neural Network Model

PRINCIPAL INVESTIGATOR: Leif H. Finkel
University of Pennsylvania
Department of Bioengineering
(215) 898-1483

R&T PROJECT CODE: 4424255 CONTRACT NO: N0001490J1864

Objective:
The objective is to uncover how the visual system perceives depth from occlusion--the situation in which one object partially blocks the view of a more distant object--and to incorporate this understanding into the design of a neural network model capable of emulating the depth perception performance of biological visual systems.

Approach:
The research approach consists of (1) developing and implementing a model of occlusion discrimination in a neural network system, (2) using this model to investigate mechanisms of integration of depth information, and (3) writing a computer simulation program to carry out a formal evaluation of the computability of the neural network model.

Progress:
A neural environment for simulating neural systems, called NEXUS, has been developed. NEXUS is based on the principles of topological map organization, and introduces a novel network construct, programmable generalized neural (PGN) units. A single PGN unit can emulate the behavior of an entire neural circuit or assembly, allowing complex systems to be simulated. Preliminary tests of a model of how the cortex extracts depth from occlusion indicate the model will fully account for the variations in the vividness of perception of a wide range of illusory contours.

TITLE: Core Support for the Committee on Vision

PRINCIPAL INVESTIGATOR: Pamela Flattau
National Academy of Sciences
(202) 334-2565

R&T PROJECT CODE: 4426125 CONTRACT NO: N0001491J1757

Objective:
Provide information on current and anticipated problems relevant to Navy and other federal agencies in the areas of vision, visual standards, and hazards to vision.

Approach:
Working groups will be formed to address specific issues identified by a sponsor. Each group will be made up of leading experts in scientific fields relevant and specific to the problem at hand, and will produce a document responsive to problem solution.

Progress:
The committee has continued to provide workshops aimed at identifying research needs in vision.

TITLE: Computational and Psychophysical Study of Human Vision Using Neural Networks

PRINCIPAL INVESTIGATOR: Donald A. Glaser
University of California, Berkeley
Department of Molecular and Cell Biology
(415) 642-7231

R&T PROJECT CODE: 4424243 CONTRACT NO: N0001490J1251

Objective:
The objective is to carry out empirical investigations to evaluate and modify current computational models of processes by which information about the physical properties of the external environment is extracted by the human visual system. Of primary interest are the investigation of detection and identification of moving objects in noisy environments, the role of global (non-local) processes in the perception of three dimensionality, the perception of flow patterns and textures, and the processes by which detectable lines and their intersections within images are labeled or assigned roles in image interpretation.

Approach:
The approach is interdisciplinary, combining empirical investigation at the level of visual psychophysics and computational modeling. Preliminary theoretical developments are used to guide the specification of empirical questions, and the resultant findings are used to evaluate and extend theoretical formulation.

Progress:
In a series of experiments it has been found that (1) perceived depth of test objects near the center of a scene seem to depend on disparities, positions, and shapes of many other objects in the field of view; and (2) these context effects can persevere over extended periods of time.

Report:
Kumar, T. and Glaser, D.A. (In Press) Influence of remote objects on local depth perception. Vision Research, 31 (10), 1687-1699.

TITLE: Electrophysiological Studies of Visual Attention and Resource Allocation

PRINCIPAL INVESTIGATOR: Steven A. Hillyard
University of California, San Diego
Department of Neurosciences
(619) 534-2385

R&T PROJECT CODE: 4426556 CONTRACT NO: N0001489J1806

Objective:
To clarify mechanisms of visual-spatial selective attention in humans, both at the level of perceptual processing and at the level of the underlying brain physiology. The focus will be on the effectiveness of different advance cueing procedures for orienting attention to regions of a visual display.

Approach:
The indices of attentional orienting to be studied are facilitation of reaction times and enhanced event-related potentials (ERPs) to stimuli at attended locations. The proposed methods will eliminate confounds that have clouded the interpretation of previous studies.

Progress:
Experiments carried out over the past three years reveal that spatial attention operates by modulating the flow of information at relatively early levels of the visual pathway; the timing and cortical localization of these attentional processes show strong parallels to those observed in neurophysiological studies of non-human primates.

Report:
Mangun, G.R. and Hillyard, S.A. (In Press) Modulation of sensory-evoked brain potentials provide evidence for changes in perceptual processing during visual-spatial priming. *Journal of Experimental Psychology: Human Perception and Performance.*

TITLE: Training in Computational Neuroscience of Vision

PRINCIPAL INVESTIGATOR: Susan Hockfield
Cold Springs Harbor Laboratory
CSH Summer Neurobiology Program
(516) 367-8861

R&T PROJECT CODE: 4424297 CONTRACT NO:

Objective:
The objective is to provide a select group of young neuroscientists with a state-of-the-art treatment of the issues and techniques of computational analysis.

Approach:
The course is two weeks in length. Each day includes both lecture/discussion periods and time on computers. A typical day runs from 9:00AM through midnight, during which time students are provided with physiological and neuroanatomical data and are trained in how to carry out a computational analysis on them leading to formal computer models.

TITLE: Planning Workshop for ONR Initiative on Image Representation in Biological and Machine Vision

PRINCIPAL INVESTIGATOR: Donald D. Hoffman
University of California, Irvine
Department of Cognitive Sciences
(714) 856-6795

R&T PROJECT CODE: 4424291 CONTRACT NO: N0001492J1513

Objective:
Synthesize and evaluate computational models of image representation in biological and machine vision.

Approach:
The conference will be organized by the PI, together with his colleagues at UC-Irvine. The meeting will consist of two days of presentations by featured speakers, discussion, and commentary. The conference will be held near Irvine, California.

TITLE: Analog Neuronal Networks for Early Vision

PRINCIPAL INVESTIGATOR: Christof Koch
California Institute of Technology
Computation and Neural Systems
(818) 356-6855

R&T PROJECT CODE: 442g006 CONTRACT NO: N0001491J1174

Objective:
Objective is to develop theoretical models of computation for early visual processes toward analog VLSI chips for use in robotic vision systems.

Approach:
Approach is to simulate analog algorithms for vision on a hypercube computer in two stages; first as independent, then as integrated processes. Explore design possibilities for silicon implementation.

Progress:
A new multi-resolution algorithm was developed for computing the 2-D velocity field from the changing retinal image. Single-scale algorithms can reliably detect movement only over a limited range of speeds; the new algorithm expands the range of velocities that can be measured and also decreases time required to integrate motion information over the area of the image. The flow field is first computed at a coarse scale, then at successively finer scales. The scheme is adaptive in that it chooses scale locally based on an estimate of the error in the velocity computation.

Report:
Battiti,R., Amaldi,E. and Koch,C. (1991) Computing optical flow across multiple scales: an adaptive, coarse-to-fine approach. Int. J. of Computer Vision.

TITLE: The Fifteenth International Symposium on Attention and Performance: Conscious and Nonconscious Information Processing

PRINCIPAL INVESTIGATOR: Sylvan Kornblum
University of Michigan
Mental Health Research Institute
(313) 763-1101

R&T PROJECT CODE: 4424290 CONTRACT NO: N0001492J1603

Objective:
Provide insights into important basic research issues in the fields of human memory, cognition, and cognitive neuroscience, and into the application of findings in these fields to address Navy needs in training and operations.

Approach:
The seven day conference will be divided into 7 sessions, each initiated with a tutorial in the field followed by a series of research papers and extended discussion of key research issues.

TITLE: The Interaction of Top-Down and Bottom-Up Processes in the Control of Attention in the Visual Field

PRINCIPAL INVESTIGATOR: Arthur F. Kramer
University of Illinois
Department of Psychology
(217) 333-2186

R&T PROJECT CODE: 4424298 CONTRACT NO:

Objective:
The objective is to develop a deeper understanding of how top-down and bottom-up processes interact in determining attentional dynamics in 3D viewing environments. Of particular interest is how a person's strategies influence the dynamic allocation of attention to preattentively defined objects and groups in the visual field.

Approach:
An approach which includes both psychophysical experimentation and computational modeling will be used in this project. Experiments will focus on (1) the flexibility of strategic attentional control; (2) the effects of attentional inhibition on processing of information which is irrelevant at one point in a task and relevant at the next; and (3) interaction of strategic and automatic control of information flow.

Progress:
This grant is new in FY 92.

TITLE: Investigation of Spread of Attention in the Visual Field

PRINCIPAL INVESTIGATOR: David La Berge
University of California, Irvine
Department of Cognitive Sciences
(714) 856-6802

R&T PROJECT CODE: 4424208 CONTRACT NO: N0001490J1447

Objective:
The objective is to test and elaborate the PI's gradient theory of visual-spatial attention. Evaluation of the theory will be based on empirical research and computer simulation.

Approach:
An extensive series of experiments will be carried out to analyze the width of attentional focus' effect, on which the PI's theory of attention is based, to explore methods to produce and sustain a focus of a given size, and to determine ways in which the focus-width effect can be exploited to optimize human performance in tasks involving object recognition.

Progress:
The results of several experiments indicate that the interfering effects of incompatible flanking stimuli can be reduced by techniques that induce a narrowing of attention around the target location. A simulation of the pulvinar circuit operations in attention has been developed. The simulation includes cross-cortical connections between columns and connections with prefrontal structures and basal ganglia structures.

Report:
LaBerge, D., Brown, V., Carter, M., Bash, D., and Hartley, A. (1991) Reducing the effects of adjacent distractors by narrowing attention. Journal of Experimental Psychology: Human Perception and Performance. 17, 65-76.

TITLE: Processing Information in the Cerebral Cortex

PRINCIPAL INVESTIGATOR: John H. Maunsell
University of Rochester
Strong School of Medicine and Dentistry
(716) 275-2076

R&T PROJECT CODE: 4424242 CONTRACT NO: N0001490J1070

Objective:
The objectives of this work are: (1) to determine if neurons that are most active when the animal searches for a specific visual stimulus also respond selectively during search for a specific haptic stimulus; (2) to determine whether individual neurons can signal task-specific information for more than one task; (3) to determine effects of training on task-specific responses of cortical neurons.

Progress:
Studies of extraretinal representation in MT and MST of macaque monkey have been completed during the past year. Surprisingly, no evidence of extraretinal representation was found in MT and relatively little was found in MST. Current work focuses on the neural representation of geometric objects.

Report:
Maunsell, J.H.R., Sclar, G., Nealey, T.A. & Depriest, D.D. (In Press). Extraretinal representation by neurons in area V4 in the visual cortex of the macaque monkey. Visual Neuroscience, 1991.

TITLE: The Role of Visual Attributes in Texture and Stereopsis

PRINCIPAL INVESTIGATOR: Thomas V. Papathomas
Rutgers University
Department of Biomedical Engineering
(201) 932-6533

R&T PROJECT CODE: 4424289 CONTRACT NO: N0001492J1312

Objective:
The main objective of this research effort is to employ a novel class of multi-attribute stimuli in a systematic study that will investigate the interaction of color and luminance in stereopsis. Of specific interest is the role of chromatic signals in resolving known ambiguities in stereograms with uncorrelated luminance signals.

Approach:
The interaction of color and luminance in stereopsis will be investigated both empirically, through psychophysical investigation with human subjects, and through computational analysis.

Progress:
This grant is new in FY 92.

TITLE: Visual Integration and Recognition

PRINCIPAL INVESTIGATOR: Tomaso A. Poggio
Massachusetts Institute of Technology
Center for Biological Information Processing
(617) 253-5230

R&T PROJECT CODE: 442g002 CONTRACT NO: N0001491J1270

Objective:
Objective is to specify biologically plausible implementation models for visual cue integration and object recognition.

Approach:
Approach is interdisciplinary collaboration in computational modeling and psychophysical experimentation. Theoretical and computational studies will model the information processing tasks involved in visual integration and recognition. Algorithms will be developed and tested on a parallel supercomputer. Computational work will guide design of experiments in human perception.

Progress:
An approach to object recognition is being pursued which equates object recognition to learning from examples. Objects are represented by a small sample of views and function approximating mechanism enables recognition of novel views. The mechanism is realized as a Hyper Basis Function network. HBF networks were trained to recognize male vs. female faces given input vectors of sixteen variables characterizing faces. The networks "discovered" relative weights differentiating the faces and reduced the number of vector dimensions from sixteen to five.

Report:
Brunelli,R. and Poggio, T. (1991) Hyper BF networks for gender classification. Technical Report MIT AI Laboratory.

TITLE: Functions of Identified Neural Areas in Selective Attention

PRINCIPAL INVESTIGATOR: Michael I. Posner
University of Oregon
Department of Psychology
(503) 686-3186

R&T PROJECT CODE: 4424233 CONTRACT NO: N0001489J3013

Objective:
The objective is to understand general principles underlying the regulation of data processing in the brain by the attentional system. Two major ideas emerging from the PI's earlier work are to be evaluated: (1) the attentional system is functionally and anatomically distinct from the data collection and execution systems on which it operates; and (2) the attentional system is defined as a set of interconnected posterior and anterior brain areas that taken together select information for focal processing.

Approach:
The approach entails the use of both behavioral (reaction time) and neuroscientific (evoked potential) techniques to investigate the relation between attention and data collection systems in the human brain. Evoked potential measures will be used to track patterns of attentional activation progressing from anterior (midline anterior cingulate to supplementary motor area) to posterior (parietal and temporal) attentional structures following the cuing of likely target locations.

Progress:
Using 32 channel ERP recordings the PI has shown two posterior activations that are related to those previously reported using PET. The first is a right hemisphere activation common to words and consonant strings that is found under right parieto-temporal electrodes at about 100 ms. The second is a distinction between words and consonant strings at about 200-250 ms that is found for posterior parietal and temporal electrodes on the left and right but is localized at T5 (left temporal) in current source density analysis.

Report:
Posner, M.I. & Carr, T.H. (In press). Lexical access and the brain: Anatomical constraints on cognitive models of word recognition. American Journal of Psychology.

TITLE: Neural Models of Depth Perception in Visual Cortex

PRINCIPAL INVESTIGATOR: Terrence J. Sejnowski
The Salk Institute
(619) 453-4100

R&T PROJECT CODE: 4424258 CONTRACT NO: N0001491J1141

Objective:
Physiological studies have shown that binocular disparity is encoded at each spatial location by the pattern of activity in a population of disparity-selective neurons. The objective of this theoretical study is to incorporate this type of disparity representation into a neural model of binocular depth perception.

Approach:
A number of computational models will be developed using recently introduced techniques for training recurrent neural networks. Of special focus is how horizontal disparity is extracted from pairs of images, how egocentric depth is computed from stereopsis and other sources of information such as eye vergence, and how different sensory cues can be fused to form an accurate representation of depth.

Progress:
Several models of the neuronal mechanisms of depth perception are currently under development using recently introduced techniques for training recurrent neural networks. Progress has already been made on combining vergence eye position with disparity to compute the absolute depth to visual targets.

TITLE: The Role of Attention in Visual Processing

PRINCIPAL INVESTIGATOR: Gordon L. Shulman
Washington University
Department of Neurology
(314) 362-7170

R&T PROJECT CODE: 4424229 CONTRACT NO: N0001489J1426

Objective:
The objective is identify the anatomical locus of a variety of attentional effects in vision which have not been investigated on a systematic basis. Both spatial and non-spatial attentional effects will be studied, using sensory adaptation as the vehicle for identifying attentional influences.

Approach:
Sensory adaptation and sensory learning effects will be investigated in the presence and absence of focused attention. Since the anatomical locus of the adaptation effects studied have been established, it is possible by this means to isolate the anatomical locus of attentional effects in the visual information processing sequence.

Progress:
The results of several experiments reveal that (1) tilt after-effects are larger when subjects attend than when they do not, indicating that attentional processes operate at the level of the visual system where such after-effects are produced, and (2) size contrast effects are greater for attended than for unattended stimuli, again implicating attention at the site of these effects in the visual system.

Report:
Shulman, G. (1991) Attentional modulation of a figural after effect. Perception (In Press).

TITLE: Constructing 3D Surface Descriptions

PRINCIPAL INVESTIGATOR: Kent A. Stevens
University of Oregon
Department of Computer Science
(503) 686-4430

R&T PROJECT CODE: 4424245 CONTRACT NO: N0001490J1472

Objective:
The objective is to develop a comprehensive theory of 3-D form perception based on the assumption of two independent representation systems for distance information: (a) for absolute distance, indicated by binocular disparity, and (b) for local object-referenced depth relations.

Approach:
Theoretical analysis, computational modeling, and psychophysical experimentation are utilized to determine the nature of surface topographic features, their interactions, and how the perception of 3D form arises in human vision from those features.

Progress:
A series of experiments is underway to determine whether discontinuity features (step edges in depth, for example) facilitate the detection of surfaces. In another series, an attempt is being made to determine whether attention is systematically allocated during surface perception.

Report:
Steven, K.A. (1990) Constructing the perception of surfaces from multiple cues. Mind and Language, 5, 253-266.

TITLE: Visual Perception and Cognition of Smoothly Curved Surfaces

PRINCIPAL INVESTIGATOR: James T. Todd
Brandeis University
Department of Psychology
(617) 736-3300

R&T PROJECT CODE: 4424241 CONTRACT NO: N0001490F0003

Objective:
During the past decade, there have been numerous algorithms proposed in the literature for computing an object's 3D form from a sequence of projected images taken from different perspectives. The objective here is to identify the key assumptions underlying these alternative algorithms and to empirically examine the relative psychophysical validity of these assumptions.

Approach:
The approach is to determine the psychophysical implications of competing models of the process by which 3D form is computed from the 2D image projected to the retinal surface, and to subject these implications to rigorous empirical test.

Progress:
Empirical results reveal that perceived 3-D structure of a surface is typically ambiguous up to an affine stretching transformation along the line of sight. Computational analysis reveals how this result could be produced by biologically plausible mechanisms for optical motion.

Report:
Todd, J.T. & Bressan, P. (1990) The perception of 3-D affine structure from minimal apparent motion sequences. Perception & Psychophysics, 48,419-430.

TITLE: Visual Perception of Features and Objects

PRINCIPAL INVESTIGATOR: Anne Treisman
University of California, Berkeley
Department of Psychology
(415) 548-0596

R&T PROJECT CODE: 4424251 CONTRACT NO: N0001492MP24002

Objective:
To conduct experimental studies on feature analysis, the perception of conjunctive features, the effects of extended practice on visual search, the role of attention, object representation for dynamic images, the maintenance of object identity, the unity or grouping of object features, and memory for visual patterns.

Approach:
Experimental studies examine the nature of the stored representation for specific features, the generality of that process for implicit and explicit memory tasks, and the dependence of perception on instructions during the acquisition of information.

Progress:
In a series of experiments it has been found that: (1) part of the similarity effect in visual search tasks is due to problems in conjoining underlying features; and (2) implicit learning of consistencies of location and of irrelevant features occurs in conjunction search but not in feature search.

Report:
Treisman, A. & Sato, S. (1990) Conjunction search revisited. Journal of Experimental Psychology: Human Perception and Performance, 16, 459-478.

TITLE: Physiological, Psychophysical and Computational Basis of Pattern Recognition, Attention, and Texture

PRINCIPAL INVESTIGATOR: David C. Van Essen
California Institute of Technology
Division of Biology
(818) 356-6823

R&T PROJECT CODE: 4425083 CONTRACT NO: N0001489J1192

Objective:
Objective is to determine how information about motion, texture and depth is represented and transformed during intermediate visual processing. Emphasis is on recognition of complex visual forms viewed by task oriented humans and primates.

Approach:
Approach is interdisciplinary and collaborative, combining computational modeling, human psychophysics and primate neurophysiology. Cortical activity in animal experiments will be traced using voltage-sensitive dyes, optical recording techniques and single unit recordings.

Progress:
Progress has occurred along a number of fronts: (1) a detailed analysis of neural structures and interconnections within and between visual, somatosensory and motor areas of primate cortex has been carried out; (2) dramatic changes in the shape and location of receptive fields in V1 neurons were observed in the presence of background motion, providing further indication that receptive fields are not immutable, as once thought; and (3) the physiological substrates of perceptual pop-out and the segregation of texture borders were illuminated.

Report:
Van Essen, D.C., Felleman, D.F., DeYoe, E.A. and Knierim, J.J. (1991) The primate visual cortex: Pathways and Perspectives. In: From pigments to perception: Advances in understanding visual processes, (Eds.) A. Valberg and B.B. Lee, Plenum, NY.

TITLE: Invariant Learning and Recognition of 3D Object-Part Hierarchies

PRINCIPAL INVESTIGATOR: Allen M. Waxman
Massachusetts Institute of Technology
Lincoln Laboratory
(617) 981-2056

R&T PROJECT CODE: 4424267 CONTRACT NO: N0001492MP24005

Objective:
To modify and extend an existing machine vision system to incorporate the invariant learning and recognition of object-part hierarchies. Such representations are well suited for recognition of variable, articulated, and occluded objects.

Approach:
The work will include both physiological experimentation with monkeys (carried out under sub-contract to D. Perrett at St. Andrews University in Scotland) and computational modeling based on the physiological findings and other findings in the literature.

Progress:
Work has begun on the construction of a database of imagery and development of a viewing sphere (for faces/heads, body parts, and military vehicles) is underway. Feature extraction methods have been defined to exploit both points of high curvature along contours, and oriented edge segments near high curvature points.

Report:
Seibert, M and Waxman, A.M. (1991) Learning and recognizing 3-D objects from multiple views in a neural system, in Neural Networks for human and machine perception (H. Wechler, Ed), Academic Press: NY, 178-215.

PERCEPTUAL SCIENCE

AUDITION

TITLE: *Classification of Complex Sounds*

PRINCIPAL INVESTIGATOR: Bruce G. Berg
University of California, Irvine
Department of Cognitive Sciences
(714) 856-7920

R&T PROJECT CODE: 4424285 CONTRACT NO: N0001492J1164

Objective:
To develop a deeper understanding of how human listeners classify and discriminate complex auditory stimuli.

Approach:
Psychoacoustic experiments will be carried out in which various features of complex acoustic patterns will be perturbed in appropriate ways, and the impact of these perturbations will be assessed by means of COSS analysis to determine what acoustic features the listener uses to classify the complex patterns.

Progress:
COSS analysis has been used in a series of experiments to estimate spectral weights in several profile analysis tasks, including (1) discrimination of broadband "rippled spectra", (2) discrimination of narrowband spectra, and (3) estimation of "temporal-spectral weights" using a three-tone profile with different durations.

Report:
Berg, B.G. and Green, D.M. (1991). Discrimination of complex spectra: spectral weights and performance efficiency. In Y. Cazals, L. Demany, and K. Horner (Eds.), Auditory physiology and perception, 9th International Symposium on Hearing. Pergamon Press.

TITLE: Range Deconvolution and Recognition Active Sonar

PRINCIPAL INVESTIGATOR: Roger Hillson
Naval Research Laboratory
(202) 404-7332

R&T PROJECT CODE: 4424287 CONTRACT NO: N0001492WX24197

Objective:
The objective is to evaluate the utility of algorithms proposed as models of the bat's target imaging capability for Navy applications. More specifically, the aims are, first, to unambiguously define the algorithms; second, to scale them with respect to frequency and target size as appropriate for Navy applications; and third, to extend them to account for significant differences in the structure of the reflected wave from a target insonified in water rather than in air.

Approach:
The approach will be to test a software simulation of the hypothesized algorithm used by echolocating bats using both hypothetical and actual sonar data and to extend or modify the algorithm so that it can operate effectively with sonar signals with attributes (e.g., elastic reverberation) that are not normally encountered by the bat.

Progress:
This project is new in FY 92.

TITLE: A Source Separation Model of the Mammalian Auditory System

PRINCIPAL INVESTIGATOR: Edwin R. Lewis
University of California, Berkeley
Electronics Research Laboratory
(415) 642-5169

R&T PROJECT CODE: 4424263 CONTRACT NO: N0001491J1333

Objective:
Develop computational models of the mammalian auditory periphery and brainstem nuclei. Derive algorithms for automated acoustic source separation based on principles uncovered by simulation and analysis of model results.

Approach:
Existing models of the cochlea and auditory nerve will be extended and interfaced with models of auditory brainstem nuclei to be developed. Model development will be done within a modular framework so that models can be easily modified to incorporate new hypotheses and adjust the level of biological detail. Model neural elements will be dynamic and generate spike trains, which are likely to be crucial for certain kinds of temporal processing. Various classes of brainstem neurons which exhibit distinct dynamic behaviors, and which are thought to mediate the generation of distinct classes of acoustic image, will be simulated. Psychophysical data on cues important for source separation will be used to constrain the model and guide hypotheses on neural mechanisms.

Progress:
During the past year software development involved: (1) transport of previously developed code for modeling cochlear and VIIIth nerve signal processing from PCAT DOS format to the SUN; (2) Modification of this code to improve modularity; (3) development of a new spike-initiator module; (4) development of display software for 3-D presentation of neural response data; (5) development of a cochlear filter module based on FFT computation; and (6) development of user-interactive software to smooth REVCOR-derived cochlear filter functions.

TITLE: Central Factors in the Classification of Transient Acoustic Signals

PRINCIPAL INVESTIGATOR: Robert A. Lutfi
University of Wisconsin
Waisman Center on Mental Retardation
(608) 262-7734

R&T PROJECT CODE: 4424226 CONTRACT NO: N0001489J1281

Objective:
The objective is to determine the role of central factors such as learning, memory, and attention in the classification of complex acoustic signals with random variation similar to that occurring in naturally occurring signals.

Approach:
Psychophysical studies of normal hearing humans will be carried out to determine listeners' ability to integrate information across a wide range of stimulus dimensions, to overcome effects of stimulus uncertainty, and to weight information according to its reliability. Quantitative modeling studies will also be carried out to evaluate hypotheses generated by psychophysical experiments. The methods of signal detection theory will be applied in both experimental and modeling components of this project.

Progress:
A theoretical analysis of traditional tone-in-noise detection masking experiments indicated that as much as 22% of the masking observed in these studies is due to uncertainty associated with trial-to-trial variation in the noise waveform rather than to masker energy falling in proximity to the tone. Empirical studies provided support for this analysis.

Report:
Lutfi, R.A. (1990). How much masking is informational masking? Journal of the Acoustical Society of America, 88, 2608-2610.

TITLE: Acoustical Cues for Sound Localization

PRINCIPAL INVESTIGATOR: John C. Middlebrooks
University of Florida
Department of Neuroscience
(904) 392-3177

R&T PROJECT CODE: 4424227 CONTRACT NO: N0001489J1427

Objective:
The technical objectives of this study are: (1) to determine possible physical cues that may be used by the central nervous system to compute sound source location by making measurements of sound pressure in the human ear canals; (2) to measure in behavioral experiments the accuracy with which humans localize broad- and narrow-band sounds presented at unknown vertical and horizontal locations.

Approach:
Both acoustical and behavioral experiments will be carried out. In acoustical experiments, transient broad- and narrow-band sounds from a movable free field sound source will be presented to human subjects while sound pressure is recorded from miniature microphones inserted into their ear canals. Spatial dependence of sound pressure levels and interaural level differences will be determined from amplitude spectra as a function of location. Interaural envelope delays will be computed from phase spectra.

Progress:
Experimental work continues on the analysis of localization of narrowband (1/6 octave bandwidth) sounds, exploration of the contributions of various portions of the external ear to its directional transfer function, and the measurement of localization behavior in patients who suffer from chronic unilateral deafness. The latter reveal the extent to which nonaural spectral cues can substitute for binaural cues for sound localization.

Report:
Middlebrooks, J.C., and Green, D.M. (1991) Sound localization by human listeners. Annual Review of Psychology, 42, 135-159.

TITLE: Representation and Detection of Stochastic Acoustic Transients Using Physiologically-Based Models

PRINCIPAL INVESTIGATOR: David C. Mountain
Boston University
Department of Biomedical Engineering
(617) 353-4343

R&T PROJECT CODE: 4424284 CONTRACT NO: N0001492J1127

Objective:
To evaluate physiologically-based models as preprocessors for acoustic transient classification systems, to discover which processes in the models are most important for model performance, and to develop general mathematical equations which effectively describe the important computations.

Approach:
The output of alternative peripheral models will be processed with a cochlear nucleus model to evaluate the systems' ability to segregate complex signals. The robustness of the models will be tested by randomly altering model parameters and randomly eliminating cells.

Progress:
This grant is new in FY 92.

TITLE: Dolphin Echolocation: Cognitive and Perceptual Processing Models

PRINCIPAL INVESTIGATOR: Paul E. Nachtigall
Naval Ocean Systems Center
Hawaii Laboratory
(808) 257-5256

R&T PROJECT CODE: 4424262 CONTRACT NO: N0001492WX24139

Objective:
To increase understanding of dolphin acoustic signal processing and to explore the potential application of empirical results for defining an effective signal parsing strategy for input to neural network classifiers.

Approach:
Perform a series of experiments testing the ability of the dolphin to classify objects by means of its active sonar system. Determine by means of synthetic returns what signal components are crucial for accurate classification. Based on the results, design the signal parsing front-end for a neural network signal classifier. Compare performance of the animal and the network.

Progress:
Animal performance in a matching-to-sample task has been measured on various echolocation discriminations while both outgoing clicks and all returning echoes have been captured and digitized for modeling. An integrator gateway network model has been developed that integrates clicks into trains prior to insertion into a neural network classifier. The network model correctly classifies echo returns from various objects in a manner similar to the performance of the dolphin.

Report:
Moore, P., Roitblatt, H., Penner, R., and Nachtigall, P. (1991) Biomimetic sonar processing: From dolphin echolocation to artificial neural networks. From Animals to Animats, Meyer, J. and Wilson, S. (Eds.), MIT Press, Cambridge, Massachusetts.

TITLE: Models for Continuous Processing of Auditory Signals

PRINCIPAL INVESTIGATOR: Robert F. Port
Indiana University
Department of Computer Science
(812) 855-9217

R&T PROJECT CODE: 4424259 CONTRACT NO: N0001491J1261

Objective:
(1) Carry out psychophysical experiments designed to determine if representations of complex tonal sequences that are learned for sequence recognition tasks are similar to those learned for discrimination tasks. Develop and extend computational models and simulations to incorporate experimentally determined ways in which representations depend on nature of task. (2) Carry out psychophysical experiments designed to determine what invariances are intrinsic to the representation of acoustic patterns in humans. Use results of these experiments to constrain and guide the computational model.

Approach:
Psychophysical experiments will be performed to investigate human auditory perception capabilities on tasks requiring identification of complex tonal sequences and discrimination of features of sequence components. The effects of changes in rate of tone presentation on performance will also be explored. Results of these experiments will be used to constrain and guide development of a recurrently connected neural network model with separate modules for processing of novel and familiar acoustic patterns.

Progress:
A network model for auditory short-term memory is under development. The model simulates human performance in auditory discrimination tasks involving complex, unfamiliar tone sequences. Psychophysical studies completed during this funding period are providing strong constraints on the model's architecture and parameters.

Report:
Anderson, S., Port, R. & McAuley, D. (1991) Dynamic memory: a model for auditory pattern recognition. Neural Computation. (In Press)

TITLE: Conference on Dynamic Representation in Cognition

PRINCIPAL INVESTIGATOR: Robert F. Port
Indiana University
Department of Computer Science
(812) 855-9217

R&T PROJECT CODE: 4424281 CONTRACT NO: N0001492J1029

Objective:
Synthesize and evaluate dynamic models of temporal pattern representation in perception, motor control, and cognition.

Approach:
The conference will be organized by the PI and a co-PI (T. Van Gelder), together with colleagues from the Psychology Department at University of Indiana. The meeting will consist of two-and-one-half days of presentations by featured speakers, discussion, and commentary. The conference will be held at University of Indiana, Bloomington, Indiana November 14-17, 1991.

TITLE: Low Frequency Sound and Marine Mammals Hearing

PRINCIPAL INVESTIGATOR: Sam H. Ridgway
Naval Command Control and Ocean Surveillance Center
(619) 553-1374

R&T PROJECT CODE: 4424301 CONTRACT NO:

Objective:
The objective is to develop and validate methods of assessing the hearing sensitivity of large marine mammals using electrophysiological methods.

Approach:
The investigator will use auditory evoked responses or brainstem recorded responses using surface mounted skin electrodes to assess the hearing thresholds of a variety of marine mammals to low frequency sound.

Progress:
This project is new in FY 92.

TITLE: Bioacoustic Signal Classification in Cat Auditory Cortex

PRINCIPAL INVESTIGATOR: Christoph E. Schreiner
University of California, San Francisco
Department of Otolaryngology
(415) 476-2591

R&T PROJECT CODE: 4424264 CONTRACT NO: N0001491J1317

Objective:
To explore the physiological principles underlying the spatio-temporal representation of simple and complex signals in the auditory cortex of the cat; and (2) to use the formalized cortical representation as the input (front end) to a self-organizing signal classifier instead of a purely acoustical/spectral representation of complex signals.

Approach:
Experiments will be carried out to map the spatio-temporal patterns of activity produced in the auditory cortex by signals of varying complexity and known acoustical properties. The signal parsing strategies so identified will be incorporated into neural network classifiers as a 'front-end'. The effectiveness of this input parsing will be evaluated in relation to more traditional methods.

Progress:
The spatial distribution of the sharpness of tuning of single neurons along the isofrequency domain of primary auditory cortex has been studied. The frequency selectivity of multiple units varied systematically along isofrequency contours, the most sharply tuned clusters appearing at the center of essentially dorso-ventrally oriented isofrequency contours. Evaluation of the monotonicity of rate-level functions of multiple unit responses also revealed a strong tendency for systematic spatial arrangement.

Report:
Chimento, T. and Schreiner, C. (1991). Adaptation and recovery from adaptation in single fibers of cat auditory nerve. J. Acoust. Soc. Amer. 90: 263-273.

TITLE: Effects of Low Frequency Sound on Pinnipeds

PRINCIPAL INVESTIGATOR: Ronald Schusterman
University of California, Santa Cruz
Institute of Marine Sciences
(408) 459-3345

R&T PROJECT CODE: 4424300 CONTRACT NO:

Objective:
To quantitatively define the hearing threshold of sea lions and elephant seals to low frequency sound in the range of 50 to 100hz.

Approach:
The P.I. will use standard behavioral methods to measure the animals response to low frequency sounds between 50 to 1000hz at octave intervals. The animal will be asked to respond to a stereotypic stimulus. If the animal does not respond the stimulus is below its hearing threshold.

Progress:
This grant is new in FY 92.

TITLE: Principles of Perception in Bat Sonar

PRINCIPAL INVESTIGATOR: James A. Simmons
Brown University
Department of Psychology
(401) 863-1542

R&T PROJECT CODE: 4424202 CONTRACT NO: N0001489J3055

Objective:
To determine the fine structure of the image of a sonar target as it is perceived by echo-locating bats and to understand the convergence of different representations of that image, i.e., psychophysical, computational, and physiological, that occur during the processes of fusion and formation.

Approach:
Target-ranging experiments employ a jittered-echo procedure to minimize the artifacts introduced by movements of the bat's head and to measure the shape of the acoustic image along an echo-delay or distance axis. Bats are trained in a two-alternative forced-choice procedure to discriminate between a simulated sonar target whose echoes alternate in delay and a simulated target whose echoes have a fixed delay for all transmissions. Echo delay is the acoustic cue used by the bat for the perception of the absolute distance to a target.

Progress:
The results of a series of experiments reveal that: (1) bats perceive images of complex sonar targets that explicitly represent the location and spacing of discrete glints located at different ranges; and (2) the bat perceives an image that is displayed in the domain of time or range. The image receives no evident spectral contribution except what is transformed into delay estimates.

Report:
Simmons, J.A., Moss, C. & Ferragamo, M. (1990). Convergence of temporal and spectral information into acoustic images of complex sonar targets perceived by the echolocating bat. Journal of Comparative Physiology, 166, 449-470.

TITLE: Classification of Sonar Transients by Human Listeners

PRINCIPAL INVESTIGATOR: James C. Solinsky
Science Applications International Corp.
(619) 546-6000

R&T PROJECT CODE: 4424261 CONTRACT NO: N0001491C0041

Objective:
(1) Develop a model and simulations of transient sonar signals. (2) Characterize and compare the auditory perceptual space of expert and non-expert listeners for passive sonar transients. (3) Identify the decision surfaces which divide the perceptual space into categories for expert and non-expert listeners. (4) Specify computational model of acoustic signal classification in humans.

Approach:
A parametric model of sonar transients will be developed using bi-modal spectra generated with a Gram-Charlier expansion. Phase will be non-Gaussian. Psychophyscial analysis will employ the technique of multi-dimensional scaling to characterize the perceptual structure for non-speech sounds and underlying perceptual space. Perceptual features will be identified by analyzing the relation between acoustic parameters and axes of the perceptual space. Probe signals will be used to characterize the classification decision surfaces for listeners with different experience levels.

Progress:
During the initial funding period, two pilot studies were completed to evaluate stimulus sets and experimental procedures, a Gram-Charlier simulation of recorded sounds was completed, subject session software was migrated from the Macintosh to the SUN-SPARC, and ACINT riders were provided for testing.

TITLE: Reactions of Bottlenose Dolphins to Manmade Noise

PRINCIPAL INVESTIGATOR: Peter L. Tyack
Woods Hole Oceanographic Institution
Biology Department
(508) 457-2000

R&T PROJECT CODE: 4424306 CONTRACT NO:

Objective:
Objective of this research is to determine if bottlenose dolphins (as representative small cetaceans) change their behavior in response to low frequency sounds.

Approach:
A series of playback experiments will be conducted in the field under natural conditions and behavioral changes observed.

Progress:
This grant is new in FY 92.

TITLE: Committee on Hearing, Bioacoustics and Biomechanics

PRINCIPAL INVESTIGATOR: Milton A. Whitcomb
National Academy of Sciences
(202) 334-2888

R&T PROJECT CODE: 4426124 CONTRACT NO: N0001487C0342

Objective:
To provide information and assess status of current programs and to make recommendations on current and anticipated problems relevant to Navy and other federal agencies in the areas of hearing, bioacoustics, and biomechanics.

Approach:
Working groups address: effects of sound on hearing of divers during deep dives; exposure limits for vibration received by personnel in tracked vehicles and helicopters; effect of sonic booms produced by future commercial supersonic transport aircraft; auditory attentional deficit; evaluation of communication systems; aging in the central nervous system as it relates to perception of speech by older persons; and reversibility of presbycusis.

Progress:
The Committee continues to provide workshops, symposia, and white papers to address important research issues in audition and the effects of noise in the workplace.

PERCEPTUAL SCIENCE

HAPTICS AND SENSORY GUIDED MOTOR CONTROL

TITLE: Cerebellum and the Adaptive Coordination of Movement

PRINCIPAL INVESTIGATOR: Michael A. Arbib
University of Southern California
Computer Science Department
(213) 740-9220

R&T PROJECT CODE: 4424293 CONTRACT NO:

Objective:
Determine the role of the cerebellum in linking together elemental motor synergies to produce complex coordinated motion. Determine the mechanisms underlying its linking action, and the neural implementation of this mechanism.

Approach:
The proposed work is the computational neuroscience component of a collaborative effort between the PI and Dr. Thach, a cerebellar neurophysiologist, to understand the role of the cerebellum in the adaptive coordination of movement. A neural network simulation will be developed that incorporates both long term plasticity and coordination and parameter setting in goal directed behavior. It will also incorporate Thach's new data on replicative representation of body maps in each of the cerebellar nuclei, which appear to control movement of multiple body parts.

Progress:
This grant is new in FY 92.

TITLE: Study of Neural Feedback and Musculo-Skeletal Mechanics in the Control of Multi-Joint Behavior

PRINCIPAL INVESTIGATOR: Emilio Bizzi
Massachusetts Institute of Technology
Department of Brain and Cognitive Science
(617) 253-5769

R&T PROJECT CODE: 4424216 CONTRACT NO: N0001490J1946

Objective:
Objective is to produce biologically plausible computational models of sensorimotor control of limb movement for potential implementation in teleoperator and robotic devices.

Approach:
The approach is a combination of neurophysiological experiments, behavioral investigations, mathematical modeling and theoretical studies of the computational tasks performed by the brain in the control of motor behavior. Model-based experiments are conducted to quantitatively model movement planning and implementation.

Progress:
In a series of experiments it was demonstrated that the spinal cord contains circuitry that, when activated, produces precisely balanced contractions in groups of muscles. These synergistic contractions generate forces that direct the limb toward an equilibrium point in space.

Report:
Bizzi, E., Mussa-Ivaldi, A. and Giszter, S. (1991) Computations underlying the execution of movement: A biological perspective. Science, 253, 287-291.

TITLE: Self-Organizing Neural Circuits for Sensory-Guided Motor Control

PRINCIPAL INVESTIGATOR: Daniel Bullock
Boston University
Cognitive and Neural Systems Department
(617) 353-9481

R&T PROJECT CODE: 4424286 CONTRACT NO: N0001492J1309

Objective:
Develop models of adaptive control via cerebellar learning of timing, force, and speed during reaching movements. Develop models that will provide insight into the neural representation of motor plans that generate complex motor sequences. Develop models of self-organizing neural networks for control of sequential movements of variable speed and variable duration.

Approach:
Model how signals from brain regions generating desired trajectory (motor cortex, parietal cortex, basal ganglia) interact at the cerebellum with signals on actual trajectory from spinal cord and muscle to control a learning process that calibrates force, speed and timing. Embed existing models of working memory into self-organizing movement planner that can read out plans with correct order and timing. Apply existing model of trajectory generation to complex sequential movements to infer how plans for these movements are neurally represented.

Progress:
This grant is new in FY 92.

TITLE: Tactile Sensing and Information Processing for Man and Machine Systems

PRINCIPAL INVESTIGATOR: Mark R. Cutkosky
Stanford University
Mechanical Engineering Department
(415) 725-1588

R&T PROJECT CODE: uri4114 CONTRACT NO:

Objective:
Develop robotic control algorithms incorporating the event-driven control strategies determined from human experimentation. Develop a description of event-driven control in humans. Develop dynamic tactile sensors, modeled after human tactile receptors. Design and create an integrated micro-sensor system that senses a variety of physical stimuli, and embed in a soft finger.

Approach:
Record sensor signals and mechanical events during basic manipulation tasks to determine relation between mechanical events, tactile signals and the control action. Develop micro-machined sensors with local processing circuitry, and a micro-machined silicon skin with web of multiple sensor types.

Progress:
This grant is new in FY 92.

TITLE: The Cortical Substrate of Haptic Representation

PRINCIPAL INVESTIGATOR: Joaquin M. Fuster
University of California, Los Angeles
UCLA School of Medicine
(213) 825-0247

R&T PROJECT CODE: 4425800 CONTRACT NO: N0001489J1805

Objective:
The primary objective of this work is to understand the functional organization of areas of primate cerbral cortex that represent tactile and visual information, with particular emphasis on the interaction of tactile and visual stimuli in the cortical representation of external objects.

Approach:
The role of posterior parietal cortex in the representation of physical objects will be explored by examining the effects of reversible cryogenic lesions of this cortical area in monkeys on short-term memory of haptically or visually perceived objects. Functional organization of parietal neurons during short term memory tasks will explored with microelectrode recording. Single unit recordings will also be analyzed to investigate neuronal mechanisms underlying attention to an object.

Progress:
Cell populations have been discovered in the somatosensory cortex which are devoted to temporary (on-line) retention of tactile information. These cells can be activated by auditory and visual inputs that are associated with tactile stimuli to be retained in temporary memory.

Report:
Fuster, J.M. (1990) Inferotemporal units in selective visual attention and short-term memory. Journal of Neurophysiology, 64, 681-697.

TITLE: Mechanisms of Eye-Hand Coordination

PRINCIPAL INVESTIGATOR: Apostolos Georgopoulos
University of Minnesota
Department of Physiology
(612) 725-2282

R&T PROJECT CODE: 4424304 CONTRACT NO:

Objective:
Determine relation between activity of neural populations in motor cortex and force and joint torques in multi-link arm tasks in primates.

Approach:
Monitor kinematic arm trajectories of the arm segments during movements of a torquable manipulandum operated by a rhesus monkey. Combine these measurements with those of the net force exerted by the arm to derive torques at the wrist, elbow and shoulder, and their interactions. Analyze relation between these measurements and patterns of simultaneously recorded single cells in contralateral motor cortex.

Progress:
Results of experiments supported on last grant show that motor cortical activity at the single cell level and neuronal population levels relate to the dynamic component of the total force exerted by the animal, but not to the total force.

Report:
Georgopoulos, A., Ashe, J., Smyrnis, N. and Taira, M. (1992). The motor cortex and coding of force. Science, 256, 1692-95.

TITLE: Neural Control Algorithms: Implementation and Testing on the Anthroform Arm

PRINCIPAL INVESTIGATOR: Blake Hannaford
University of Washington
Department of Electrical Engineering
(206) 543-4043

R&T PROJECT CODE: 4424288 CONTRACT NO: N0001492J1401

Objective:
Develop a robotic arm controller based on principles of motor control. Integrate the controller with a robotic arm whose design is based on known principles of biomechanics. Explore theories of motor control with this integrated system.

Approach:
A novel digital controller will be integrated with a biomechanically accurate arm in a hierarchy of organizational levels, from individual muscle to single joint to multi-segment functions. The arm will be used as a test bed for theories of motor control that attempt to explain functions determined by biomechanics and spinal cord operation.

Progress:
This grant is new in FY 92.

TITLE: Novel Robotic Actuators

PRINCIPAL INVESTIGATOR: John Hollerbach
McGill University
Department of Biomedical Engineering
(514) 398-8080

R&T PROJECT CODE: 4424282 CONTRACT NO: N0001492J1270

Objective:
Provide insights into important basic research issues in the fields of novel actuators materials development, configuration, and control, mechanics and control of muscle, and implications of novel actuators for the development of autonomous intelligent robotic systems.

Approach:
The two day workshop consisted of a day-and-a-half of presentations of research findings in participants' own fields, and a half-day of discussions aimed at resolving specific issues related to the development of an ONR interdisciplinary program in novel robotic actuators.

TITLE: Micro Electro Mechanical Systems for NSF/NASA/DOD Applications Workshop

PRINCIPAL INVESTIGATOR: Stephen C. Jacobsen
University of Utah
Center for Engineering Design
(801) 581-6499

R&T PROJECT CODE: 4424303 CONTRACT NO:

Objective:
To provide information on the emerging technology of micro-electro-mechanical systems (MEMS) technology and identify possible applications to potential users in the DOD and NASA communities. To provide a comprehensive document of progress to date and opportunities in the field of MEMS.

Approach:
A two day workshop will be held in Washington, D.C. with about 100 attendees.The first day will be devoted to six formal presentations given by experts in the field, each of which will be followed by a question period. The second day will be devoted to working-group discussion of potential applications and presentations of group discussion summaries.

TITLE: Sensorimotor Control of Dexterous Manipulation in Humans

PRINCIPAL INVESTIGATOR: Roland S. Johansson
University of Umea
Department of Physiology
46-90-165490

R&T PROJECT CODE: 4424305 CONTRACT NO:

Objective:
(1) Determine how fingertip force and the mechanical events during rolling, sliding, and making and breaking contact, are encoded in tactile afferents. (2) Explore how tactile information relating to rolling, sliding, making and breaking contact is used in control of manipulation tasks. (3) Explore encoding of fingertip movements and positions by cutaneous input.

Approach:
Make mechanical and neural and EMG measurements while human subjects perform manipulation and exploration tasks. Determine what physical parameters need to be sensed for the performance of each class of manipulation and exploration task, and how information is encoded in the pattern of neural signals in the population of afferents.

Progress:
Parallel operation of largely independent digit-specific mechanisms intermittently adjust the force applied to objects on the basis of sensory information originating from the area of contact. During manipulation of "active" objects that apply perturbing forces to the subject, grip control relies more regularly on somato-sensory input that when manipulating passive objects. The cutaneous strain encoded by tactile mechanoreceptors is probably the most relevant stimulus.

Report:
Johansson, R., Macefield, G., and Hager, C. (1991). Signals in cutaneous afferents triggering grip force responses during restraint of an object held by finger and thumb. Neuroscience Letters. Suppl. 4, p. 97.

TITLE: Motor Learning in Speech and Limb Movements: A Computational Approach

PRINCIPAL INVESTIGATOR: Michael I. Jordan
Massachusetts Institute of Technology
Department of Brain and Cognitive Sciences
(617) 253-1696

R&T PROJECT CODE: 4424253 CONTRACT NO: N0001490J1942

Objective:
The overall objective is the development of a computational theory of the production of coordinated movement in biological systems, both of the limbs and of the vocal apparatus.

Approach:
The approach will entail implementation of simulation models of an arm and a vocal tract. Two-joint and three-joint arm models will be simulated using standard rigid body dynamical equations, and will include simulated agonist and antagonist muscles at each joint based on a simple model of muscle dynamics. Vocal tract modeling will involve (1) a geometric model that relates articulator positions to vocal tract area functions, and (2) an acoustic model that combines vocal tract area functions with a source model to produce an acoustic spectrum.

Progress:
A novel computational technique, called the moving basin technique, for utilizing forward models in the adaptive control of movement has been developed. It allows the learner to utilize intermediate goals in the acquisition of a complex task. It has been used to learn inverse dynamics of a simulated four degree of freedom three-dimensional dynamic arm.

Report:
Jordan, M. and Rumelhart, D. (1992). Supervised learning with a distal teacher. Cognitive Science, in press.

TITLE: Coordination Dynamics for Neural and Robotic Control

PRINCIPAL INVESTIGATOR: J. A. S. Kelso
Florida Atlantic University
Center for Complex Systems
(407) 367-2230

R&T PROJECT CODE: 4424296 CONTRACT NO:

Objective:
Understand how new degrees of freedom are recruited according to task demand. Extend coordination dynamics to the problem of trajectory formation. Extend control principles to complex multi-degree of freedom motions and visual motor integration.

Approach:
Conduct psychophysical and motor performance experiments with human subjects and carry out non-linear dynamical systems analysis of the results of these experiments that will lead to principles of nonlinear control for coordinated motor systems.

Progress:
Frequency and speed were identified as control parameters that move the system through collective states. Spatial orientation has also been identified as a control parameter. Ordered coordinations arise spontaneously as a result of changing control parameters and random fluctuations allow the system to find new forms of coordination.

Report:
Zunone, P. and J.A.S. Kelso (1992). Evolution of behavioral attractors with learning: non-equilibrium phase transitions. J. Exper. Psych., 18, 2.

TITLE: Out-of-Plane Microactuator Demonstration

PRINCIPAL INVESTIGATOR: Gregory T. Kovacs
Stanford University
Electrical Engineering, CIS
(415) 725-3637

R&T PROJECT CODE: g43f001 CONTRACT NO:

Objective:
Develop and test mathematical models of out-of-plane microactuators based on both electrostatic actuation and differential thermal expansion. Develop and test the out-of-plane actuator and some demonstration applications such as a micro-gripper, micro-cilia array, and a "micro-millipede" using out-of-plane actuators.

Approach:
Use electrostatic normal forces and/or differential thermal expansion to actuate an articulating digit. Coordinated arrays of two or more digits will be used as a gripper. A two dimensional array of group addressable actuators will serve as cilia/millipede arrays. Actuators will be machined by micro-fabrication methods.

Progress:
This grant is new in FY 92.

TITLE: Peripheral Neural Mechanisms of Haptic Touch: Softness and Shape

PRINCIPAL INVESTIGATOR: Robert H. LaMotte
Yale University
School of Medicine
(203) 785-2802

R&T PROJECT CODE: 4424218 CONTRACT NO: N0001491J1566

Objective:
The objective is to develop the psychophysical and neurobiological basis for biologically plausible computational models of human hand grasping and object manipulation for potential implementation in teleoperator and robotic devices. A computational theory of touch will be developed.

Approach:
Psychophysical data from humans and monkeys and physiological data from monkeys will be gathered to determine the capabilities of these systems to discriminate softness and shape, and to determine the neural code underlying these discrimination capabilities. Concepts from mechanics of deformable media and adaptive control theory will be used in the development of computational theory of touch.

Progress:
Progress have been made in developing the apparatus required to carry out the proposed work, including adding a forth axis to the three axis translation device used to apply objects to skin and developing a precise method for machining plexiglass test objects. Identification procedures and control algorithms required to achieve desired manipulation of compliant objects have been developed.

Report:
Annaswamy, A.M. and Srinivasan, M.A. (1991) Adaptive control for grasping and manipulation with compliant fingerpads. Proceedings of the 1991 ACC, Boston.

TITLE: Neural Networks With Local Receptive Fields

PRINCIPAL INVESTIGATOR: W. Thomas Miller
University of New Hampshire
Dept. of Electrical & Computer Engineering
(603) 862-1326

R&T PROJECT CODE: a44e021 CONTRACT NO:

Objective:
Develop neural network architectures and learning criteria that will enable both stable incremental learning and enhanced generalization in large networks carrying out robotic control.

Approach:
Compare CMAC with radial basis function networks by relating their function approximation capabilities to network characteristics such as receptive field distribution and shape. Develop hybrid networks that combine advantages of these two networks. Explore improvement in generalization performance from the use of fault-tolerance enhancing algorithms and architectures with long-term and short-term memory subnetworks.

Progress:
(1) Demonstrated that CMAC neural net controllers have superior performance to traditional adaptive control techniques for systems with unmodeled dynamics, complex models, or sensor noise. (2) Implemented CMAC controlled robotic planning for a robot with 2 arms and active binocular vision and for gait generation in a legged walker. (3) Produced VLSI chips implementing CMAC associative memory and radial basis function networks, and board-level implementations for VME and PC-AT bus, which were made commercially available.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Contact Biomechanics in Tactile Sensing

PRINCIPAL INVESTIGATOR: Mandayam Srinivasan
Massachusetts Institute of Technology
Research Laboratory of Electronics
(617) 253-2512

R&T PROJECT CODE: 4424268 CONTRACT NO: N0001491J1454

Objective:
Obtain dynamic video images of fingerpad contact areas; measure forces of contact between fingerpads and objects varying in shape, compliance, and texture during active and passive touch. Use results to explain the biomechanical processes that give rise to physiological and psychophysical data, and also to specify inputs to computational model of touch sensing.

Approach:
Video microscopy will be used to record high resolution images of contact regions between fingerpads and transparent test objects for two extremes of magnification, from the whole pad to single ridges. A tactile stimulator will apply test objects to the passive fingerpad. Data will also be collected during active touch. contact modes will include normal, tangential without slip, and tangential with slip. Artificial tactile sensor arrays will be used in some experiments to measure force distribution within the contact region.

Progress:
During the past year a force sensing system and a videomicroscopic system, both interfaced to a computer, have been designed. In addition, preliminary experiments have begun on (1) alternative illumination techniques, one using the principle of total internal reflection, and the other with co-axial lighting; and (2) the use of stereomicroscope vs. video zoom lens attachments.

Report:
Srinivasan, M.A. (1991) Tactual interfaces: the human perceiver. In N. Durlach, T. Sheridan, and S. Ellis (Eds.) *Human-machine interfaces for teleoperators and virtual environments*. NASA Conference Publication.

TITLE: Cerebellum and the Adaptive Coordination of Movement

PRINCIPAL INVESTIGATOR: W. Thomas Thach
Washington University
Department of Anatomy and Neurobiology
(314) 362-3538

R&T PROJECT CODE: 4424292 CONTRACT NO:

Objective:
Determine the role of the cerebellum in linking together elemental motor synergies to produce complex coordinated motion. Determine the mechanism underlying its linking action, and the neural implementation of this mechanism.

Approach:
Neurophysiological experiments will be carried out on monkeys trained to perform reaching movements to targets. Kinematics will be constructed from video analysis, EMG will be recorded, and single unit recordings of cerebellar neurons and neurons in downstream nuclei will be made during reaching movements. Parts of the cerebellum and downstream nuclei will be reversibly inactivated to examine effects on coordination of reaching, preshaping and grasping.

Progress:
This grant is new in FY 92.

PERCEPTUAL SCIENCE

HUMAN FACTORS TECHNOLOGY AND BIOPSYCHOMETRIC ASSESSMENT PROGRAMS

TITLE: Automatic Characterization of the Human Operator Dynamics and Its Incorporation into Telerobot Control

PRINCIPAL INVESTIGATOR: John M. Hollerbach
McGill University
Department of Biomedical Engineering
(514) 398-6736

R&T PROJECT CODE: 4424239 CONTRACT NO: N0001490J1849

Objective:
To develop scientific instrumentation and methods for the analysis of single joint, quasi-static movement in human operators and manipulators. To utilize knowledge of human operator dynamics to improve teleoperation of the manipulator for pursuit tracking.

Approach:
Determine the mechanical properties of the actuator linkage of the experimental apparatus. Determine overall human operator dynamics in visual pursuit tracking of position with several forms of target presentation. Apply a random force-step to the wrist of human operators and instruct the operator to resist that force in such a way that the elbow joint does not change. Several methods are developed to indicate when the elbow angle has been perturbed by the force step.

Progress:
Significant progress has been made in developing measures of human control subsystem components as required to determine operator dynamics for application in the control of teleoperated systems. These submeasures have now been combined and have been shown effective, combinatorially, in predicting overall system performance.

Report:
Hollerbach, J.M. (1990). Grasping in human and robot hands. Vision and action: the control of grasping. M.A. Goodale, ed. Ablex Publ. 243-274.

TITLE: Human Signal Detection in Virtual 3D Sound Fields

PRINCIPAL INVESTIGATOR: Jerry Kaiwi
Naval Command Control and Ocean
Surveillance Center
(619) 553-9220

R&T PROJECT CODE: 4424299 CONTRACT NO: N0001492WX24284

Objective:
The objective is to investigate how people listen to and process each of several simultaneous spatial channels relative to how they listen to and process a single spatial channel.

Approach:
Yes-no and forced choice signal detection tasks will be used to compare performance in single spatial channel listening with multiple spatial channel listening. The effects of divided attention will be evaluated quantitatively by comparing pre- and post-cued multiple spatial channel performance. Masking effects will be quantified by comparing single spatial channel performance with post-cued multiple spatial channel performance.

Progress:
This project is new in FY 92.

TITLE: Cognitive Sensory Processing

PRINCIPAL INVESTIGATOR: Steven L. Speidel
Naval Ocean Systems Center
(619) 553-1557

R&T PROJECT CODE: 4424294 CONTRACT NO:

Objective:
The objective is to develop a biologically-inspired model of acoustic signal processing and to apply a computer simulation of this model to the processing of inputs to acoustic sensor arrays in the undersea environment.

Approach:
This project builds on the PI's earlier work on neural beamforming. In the current effort, a cochlear preprocessor and a stimulus segmentation algorithm derived from von der Malsberg will be added to the beamforming system to provide a more complete, biologically constrained system for acoustic signal analysis. The resulting model will be evaluated with actual sonar data taken from acoustic sensor arrays located in an undersea environment.

Progress:
This project is new in FY 92.

TITLE: An Integrated Computational Model of a Complex Human Behavior

PRINCIPAL INVESTIGATOR: William R. Uttal
Arizona State University
Department of Psychology
(602) 965-8634

R&T PROJECT CODE: 4429011 CONTRACT NO: N0001491J1456

Objective:
To conduct simulations that test a software system for the integration of existing algorithms for the detection, localization, and classification of 3-D objects in the underwater environment. To evaluate the general utility of the simulation as a test bed for refinements of the computational algorithms.

Approach:
To collect and integrate a collection of individual computational algorithms into a coherent software system capable of simulating the performance of a 'swimmer' that is required to detect and recognize regular geometrical objects, locate them in 3-D space, and then navigate toward them.

Progress:
During the past year a fourth version of the PI's computational vision model was created. This version contains a stereo vision system which, when coupled with an upgraded two dimensional image segmenter, gives both good outlines and good depth. In addition, a number of important new utility programs were completed, including a slide maker, a snapshot routine, and a frame grabber.

Report:
Shepherd, T., Uttal, W.R., Dayanand, S. and Lovell, R. A method for shift, rotation, and scale invariant pattern recognition using the form and arrangement of pattern-specific features. Pattern Recognition, In Press.

TITLE: Development and Evaluation of High Resolution Virtual Auditory Displays

PRINCIPAL INVESTIGATOR: Frederic L. Wightman
University of Wisconsin
Waisman Center on Mental Retardation
(608) 262-3822

R&T PROJECT CODE: 4424308 CONTRACT NO:

Objective:
To develop and evaluate principal components-based techniques for improving the resolution and effectiveness of virtual auditory displays.

Approach:
To develop principal components analysis and approximation theory to fit radial basis functions to the space of empirically derived pinna transfer functions, and to empirically compare the quality of sound source localization provided by these approaches.

Progress:
This grant is new in FY 92.

TITLE: Electrophysiological Studies of Visual Attention and Resource Allocation

PRINCIPAL INVESTIGATOR: Steven A. Hillyard
University of California, San Diego
Department of Neurosciences
(619) 534-2385

R&T PROJECT CODE: 4424307 CONTRACT NO:

Objective:
To evaluate the utility of evoked-potential methods for the on-line assessment of operator cognitive states during tasks requiring the monitoring of several sources of information.

Approach:
An irrelevant probe technique is employed to elicit event-related potentials to index the allocation of attention between competing tasks and competing sensory channels.

Progress:
This grant is new in FY 92.

TITLE: Biopsychometric Assessment of Workload and Performance Decrements

PRINCIPAL INVESTIGATOR: Arthur F. Kramer
University of Illinois
Institute of Aviation
(217) 333-2186

R&T PROJECT CODE: 4424295 CONTRACT NO:

Objective:
To evaluate the effects of task demands that are encountered within the SLQ-32 system (e.g., variations in memory load, information integration, hypothesis testing) through application of measures of performance effectiveness and electrophysiological measures such as the event-related potential.

Approach:
The approach includes (1) performance of a cognitive task analysis of the SLQ-32 operator, (2) design and execution of a number of realistic 20-30 minute "missions", and (3) analysis of the relationship between electrophysiological and performance data within each mission in an effort to characterize the utility of evoked potentials and electroencephalographic data for performance prediction.

Progress:
This grant is new in FY 92.

TITLE: Brain Activity and Cognition: Advanced Signal Analysis Using the Wavelet Transform

PRINCIPAL INVESTIGATOR: Leonard J. Trejo
Navy Personnel Research and Development Center
Neurosciences Division
(619) 553-7711

R&T PROJECT CODE: 4426141 CONTRACT NO:

Objective:
Current analyses of ERP and EEG data features (eg peaks) assume the signal to be stationary. The wavelet transform is a new signal processing tool currently being applied to nonstationary signals. Efficient methods for dealing with signal/noise nonstationarity and correlation among ERP features would greatly improve the utility of ERP data for cognitive task analysis and performance prediction.

Approach:
Wavelet transform will be applied to ERP data acquired by the Biopsychometric Assessment Project and the Surface Combat Operator Training Project. The approach will be to maximally enhance the S/N of ERP activity over background EEG.

Progress:
This project is new in FY 92.

BIOLOGICAL INTELLIGENCE

COMPUTATION IN LARGE NEURAL NETWORKS

TITLE: Changes in Neuronal Network Properties Induced by Learning and Synaptic Plasticity: A Nonlinear Systems Approach

PRINCIPAL INVESTIGATOR: Theodore W. Berger
University of Pittsburgh
Department of Behavioral Neuroscience
(412) 624-4562

R&T PROJECT CODE: 4426817 CONTRACT NO: N0001490J4000

Objective:
Investigate potential changes in system properties of the hippocampus induced by discrimination reversal conditioning of the nictitating membrane (NM) response. Secondly, to produce a computational structure which simulates the hippocampal system functions of learning and memory.

Approach:
The approach is a two-phase study of the functional network properties of the hippocampal formation, a brain structure long known to be critical for learning and memory functions. The first phase utilizes nonlinear systems analytic techniques to characterize the transformational properties of networks of neurons comprising the hippocampus, and in defining the contributions to network properties of individual subpopulations of hippocampal neurons. The second phase, involves the formulation of a state-space model of hippocampal system based on results from nonlinear characteristics of the hippocampus.

Progress:
New findings provide the first evidence for the induction of both LTP and LTD of NMDA receptor-mediated synaptic transmisssion and demonstrate that the level of postsynaptic depolarization can determine which of the two forms of synaptic plasticity is expressed in response to an identical afferent signal.

Report:
Xie, X., Berger, T.W. and Barrionuevo, G. (1992). Isolated NMDA receptor-mediated synaptic responses express both LTP and LTD. Journal of Neurophysiology, 67, 1013.

TITLE: Computational Theory and the Olfactory System

PRINCIPAL INVESTIGATOR: James M. Bower
California Institute of Technology
Division of Biology
(818) 356-6817

R&T PROJECT CODE: 4426136 CONTRACT NO: N0001491J1831

Objective:
The overall objective is to forge a link between the components of abstract neural network processing and the detailed anatomy and physiology of an actual neural system. This effort links the more theoretical neural network models studied by Hopfield to the actual structural components of the olfactory system studied by Bower.

Approach:
This project will develop physiological techniques for recording neuronal activity in behaving animals (albino rats). Initially, this approach will involve recording simultaneously from numerous neurons in the mitral cell layer of the olfactory bulb while the animal is performing olfactory discrimination tasks. In these experiments, the primary objective will be to determine the nature of stimulus encoding in the olfactory system and the role of this encoding in learning and memory.

Progress:
PI has incorporated a neuromodulator feature (based on experimental work with acetylcholine) that increases the memory capacity of the present pyriform cortex based network.

Reports:
Hasselmo, M.E. and Bower, J.M. (1992). Cholinergic suppression specific to intrinsic not afferent fiber synapses in rat olfactory cortex. Journal of Neurophysiology, 67, 361-369.

Hasselmo, M.E., Anderson, B.P. and Bower, J.M. (1992). Cholinergic modulation of cortical associative memory function. Journal of Neurophysiology, 67, 201-208.

TITLE: Theoretical and Experimental Research into Biological Mechanisms Underlying Learning and Memory

PRINCIPAL INVESTIGATOR: Leon N. Cooper
Brown University
Center for Neural Science
(401) 863-2172

R&T PROJECT CODE: 4426830 CONTRACT NO: N0001491J1316

Objective:
Detailed objectives include the following: to clarify the dependence of learning on synaptic modification, to elucidate the principles that govern synapse formation or modification--both local factors and global information such as that which may be delivered and/or mediated by neuromodulators, to use principles of organization that can account for observations on a cellular level to construct network models that can compute, and reproduce higher level cognitive acts.

Approach:
Approaches include both theory and experiment. Theoretical and experimental consequences of the hypothesis that synapse modification is dependent on local information (in visual cortex) in accordance with theoretical ideas the authors have developed, as well as by global instructions affecting large numbers of synapses and coming from neuromodulators. Various principles that appear to be operating on the cellular level will be used to construct models of higher level functions, including various network models for memory storage, computation and language acquisition.

Progress:
PI has presented a formulation demonstrating the connection between the unsupervised BCM learning rule and various statistical methods, in particular, that of projection pursuit. Various applications of the BCM rule have been demonstrated.

Report:
Intrator, N. and Cooper, L.N. (1992). Objective function formulation of the BCM theory of visual cortical plasticity: statistical connections, stability conditions. Neural Networks, 5, 3-17.

TITLE: Net Technical Assessments of ANN (Neural Network) Technologies

PRINCIPAL INVESTIGATOR: Robert B. Davidson
Science Applications International Corp.
Technology Research Group
(703) 821-4418

R&T PROJECT CODE: a44f003 CONTRACT NO: N0001489C0243

Objective:
The objective of the study is to: (a) evaluate the comparative performance capability of neural networks applied to signal processing tasks (incl: sonar signal identification, and automatic target recognition), and (b) evaluate the emerging national and international technological capabilities in this area.

Approach:
Preparation of a computerized database of neural network technology involves (a) a thorough review and analysis of publications, and technical reports, and (b) host symposia of nationally recognized experts on neural network theory and technology. Three state-of-the-art symposia will be conducted on the three main topics of the DARPA program: (a) Comparative Performance of Neural Networks, (b) Theory & Modelling, and (c) Hardware Technology.

Progress:
Developed and updated a database on neural network activities worldwide, including DARPA funded efforts. This database management system was written in 4th Dimension for Macintosh. Prepared briefing materials summarizing state of this technology. Delivered invited talks at two national conferences in ocean engineering. Organized and hosted 2 conferences and a workshop on neural net research and produced reports based on proceedings.

Report:
DARPA Artificial Neural Network Technology, Proceedings 1991 Program Review.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Nonlinear Neurodynamics of Biological Pattern Recognition

PRINCIPAL INVESTIGATOR: Walter J. Freeman
University of California, Berkeley
Department of Molecular & Cell Biology
(415) 642-0120

R&T PROJECT CODE: 4426318 CONTRACT NO: N0001490J4054

Objective:
The PI will develop, test and apply an instrument for pattern recognition which embodies the principles and algorithms that underlie this process in vertebrate brains.

Approach:
By detailed inspection and analysis of experimental data, which the PI views as trajectories in 3-D and 4-D projections of the phase space of the dynamic system representing the cerebral cortex, he has developed a detailed model of the process of perception in the olfactory system. Earlier work from visual and somatosensory cortices suggests this model of perception holds true for all sensory systems. The PI will build a classification device based on these neural network principles.

Progress:
Demonstrated the capability of a distributed system with global chaos to classify multiple 2-D data sets. Improvements include use of spatial patterns of RMS amplitude instead of means as the basis for the classification of outputs; an increase in the number of classes from 2 to 5; 600x increase in speed of computation; and shortened state transition times.

Report:
Shimoide, K. and Freeman, W.J. (1992). Modeling of chaotic dynamics in the biological system and application to speech recognition. Proceedings of the International Joint Conference on Neural Networks, 4, 655-660.

TITLE: Workshop in Computational Neuroscience at the Marine Biological Laboratory

PRINCIPAL INVESTIGATOR: Leslie D. Garrick
Marine Biological Laboratory
(508) 548-3705

R&T PROJECT CODE: 442h017 CONTRACT NO: N0001492J1442

Objective:
To hold three week-long workshops ('92, '93, and '94) at Woods Hole on some aspect of computational neuroscience.

Approach:
Prof. Terrence Sejnowski is the primary workshop organizer. In August 1992 there will be about 20 workshop invitees. About one-half will be alumni from previous workshops to insure continuity. Several of the participants this year will focus on the motor system.

TITLE: An Information Theoretic Approach to Distributed Inference and Learning

PRINCIPAL INVESTIGATOR: Rodney Goodman
California Institute of Technology
Department of Electrical Engineering
(818) 356-3677

R&T PROJECT CODE: a44p001 CONTRACT NO:

Objective:
The objective is to develop neural network models that are explicit and which combine elements of sub-symbolic connectionist models and artificial intelligence models.

Approach:
Investigation will be made of the interaction of human experts with rule-based networks, and the ability of these networks to model and robustly compute probabilities in the presence of noise. Determine the relationship of hybrid nets combining rule-based models with basis functions to fuzzy systems with regard to classification and function approximation. Investigate architectures, inference strategies, and incremental learning algorithms for networks which store a massive number of examples. Algorithms which discover temporal structures in data will be developed. These models will be evaluated on tasks in image understanding, speech recognition, fault diagnosis, and non-linear control of a model helicopter.

Progress:
This grant is new in FY92.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Time and Scaling in Biologically-Based Algorithms

PRINCIPAL INVESTIGATOR: Richard Granger
University of California, Irvine
Information and Computer Science Department
(714) 856-6360

R&T PROJECT CODE: a44e009 CONTRACT NO: N0001492J1625

Objective:
The overall objective is to analyze and simulate biological networks with anatomically-specified architectures and physiological function in order to develop novel algorithms applicable to complex stimuli, and temporal sequences, and to characterize the capacity and scaling properties of these nets.

Approach:
The investigators are developing a set of vertically integrated circuit designs based on the physiology and anatomy of real synapses, dendrites, local-circuits and large nets, and horizontally integrated across modules that correspond to distinct brain regions. By means of simulations and analysis of the dominant features of these vertically and horizontally integrated circuits, new architectures for signal classification of temporal sequences are developed.

Report:
Coultrip, R., Granger, R. and Lynch, G. (1992). A cortical model of winner-take-all competition via lateral inhibition. Neural Networks, 5, 47-54.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Research on Artificial Neural Network Methods and Applications

PRINCIPAL INVESTIGATOR: Morgan K. Grover
Defense Group Inc.
(213) 394-8599

R&T PROJECT CODE: a44f006 CONTRACT NO: N0001489C0175

Objective:
The objectives of the research are: (1) to define and technically characterize a range of important DoD sensor and communications signal processing functions which could be enhanced by emerging neural net technologies, (2) to conduct digital simulations of specific applications, and (3) to identify potential hardware methods and additional neural net research needed for full-scale implementation.

Approach:
Priority DoD missions in pre-output signal processing which might be enhanced by neural net methods will be evaluated. These applications will be taken from the areas of: (1) digital communications, (2) radar sensors, (3) sonar sensors, (4) laser systems, and (5) passive optical systems. For selected applications, digital simulations will be conducted using multilayer neural networks appropriate for the application, including training sequences, evaluation of error rates, retraining after system perturbation, and comparison with alternative training procedures. Based upon these results probable neural network architectures will be defined in greater detail, including quantitative estimates of network size and speed, and potential approaches for hardware implementation identified.

Progress:
The PI developed a Recurrent Detector-Predictor net and demonstrated it on a task of predicting target tracks from noisy 2D sensor array inputs. He subsequently developed a multi-class fusion architecture for tracking multiple targets. He also successfully demonstrated the value of artificial neural nets for combatting the effects of jamming on communications links.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Training in Methods In Computational Neuroscience

PRINCIPAL INVESTIGATOR: Harlyn O. Halvorson
Marine Biological Laboratory
(508) 548-3705

R&T PROJECT CODE: 442h005 CONTRACT NO: N0001491J1739

Objective:
The primary aim of the course is to provide the 20 participants with the tools to simulate the functional properties of those neural systems of interest as well as to understand the general advantages and disadvantages of this experimental approach.

Approach:
The lectures are presented by the course directors (James Bower & Christof Koch-Caltech) and invited faculty including Paul Adams, Dan Alkon, Richard Andersen, John Hildebrand, John Hopfield, Rudolfo Llinas, John Rinzel, David Rumelhart, Idan Segev, Terrence Sejnowski, David Van Essen and Christof Von der Malsburg. The computer laboratory provides students with the opportunity to begin simulations of neural systems. The lab will be equipped with Sun graphics workstations running the General Network Simulation System which was created with ONR support by James Bower.

Progress:
A total of 23 students were enrolled in this advanced course, which covered a range of topics in computational neuroscience. A number of substantive student projects were undertaken and several of these will be expanded upon within ONR supported laboratories. Based on the hands-on experience with neural simulator software, computational modelling will be expanded to a number of neurobiology laboratories where previously only experimental approaches were utilized.

TITLE: Self-Organizing Neural Network Architectures for Incremental Learning, and Pattern Recognition

PRINCIPAL INVESTIGATOR: Stephen Grossberg
Boston University
Department of Cognitive and Neural Systems
(617) 353-7857

R&T PROJECT CODE: a44j005 CONTRACT NO:

Objective:
The objective is to develop self-organizing neural models capable of incremental learning, pattern recognition, hypothesis testing and prediction within noisy, nonstationary complex images.

Approach:
Multi-channel ARTMAP networks will be developed suitable for image processing or data fusion. Comparative performance of Fuzzy ARTMAP and ARTMAP 2 will be performed using databases with incomplete and noisy data. An ARTMAP 3 will be developed based on a synthesis of ARTMAP 2 and ART 3 heuristics and evaluated on data fusion problems. A multistage image processor system will be combined with ARTMAP to autonomously discover which combinations of scene properties predict object recognition performance.

Progress:
This grant is new in FY92.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Hippocampal Modulation of Associative Learning

PRINCIPAL INVESTIGATOR: Zafra Lerman
Columbia College Chicago
Science and Mathematics Department
(312) 663-1600

R&T PROJECT CODE: 4426322 CONTRACT NO: N0001491J1764

Objective:
Real-time descriptions of behavior and neural activity will be simulated and contrasted with relevant experimental data including latent inhibition, blocking, overshadowing, and acquisition-extinction.

Approach:
The PI will complete a biologically constrained hippocampal model and test its predictions in biological experiments.

Progress:
PI has constructed network that describes behavior in real time, includes inputs that are connected to the output directly as well as indirectly through the hidden-unit layer and employs a biologically plausible backpropagation procedure to train the hidden-unit layer.

Report:
Schmajuk, N. and DiCarlo, J. (1992). Stimulus configuration, classical conditioning, and hippocampal function. Psychological Review (in press).

TITLE: Analysis and Simulation of a Cortical Network

PRINCIPAL INVESTIGATOR: Gary S. Lynch
University of California, Irvine
Department of Psychobiology
(714) 856-4274

R&T PROJECT CODE: 442h010 CONTRACT NO: N0001489J1255

Objective:
The objective is an understanding of the types of learning operations carried out by simple cortical networks. This requires research at four different levels: (1) neurobiology, (2) simulations and mathematical analysis, (3) behavioral neurophysiology (i.e., chronic recording), and (4) behavior. Results obtained in each of these areas will be used to inform, guide, and constrain studies at the other levels, as well as providing tests of predictions arising from the model being constructed.

Approach:
Researchers have historically sought to investigate the remarkable memorial capacities of brain by trying to identify physiological, anatomical, or chemical correlates of specific types of behavioral learning. This effort goes in the reverse direction. The PI's first ask how complex sets of physiological variables govern the collective activity of neurons in brain networks, and second if these aggregate activities might produce recognizable behavioral events. Using this strategy, they hope to develop general formulations stated in basic biological terms that relate physiology and anatomy to particular aspects of memory.

Progress:
Results from a biophysical model constructed to study physiological characteristics of LTP induction led to the prediction that subsequent expression of the potentiation would yield maximal depolarization in response to the temporal sequence that induced the potentiation. Such an effect amounts to the creation of "sequence detectors" that respond preferentially to the sequences on which they were trained.

Report:
Granger, R., Whitson, J., Larson, J., and Lynch, G. (1992). Non-Hebbian properties of LTP enable high-capacity encoding of temporal sequences. Proceedings of the National Academy of Sciences (in press).

TITLE: Computation and Neural Systems Meeting and Workshop

PRINCIPAL INVESTIGATOR: John P. Miller
University of California, Berkeley
Department of Cell and Molecular Biology
(510) 642-9045

R&T PROJECT CODE: 4426440 CONTRACT NO:

Objective:
The meeting is intended to bring together experimental and theoretical neurobiologists along with engineers, computer scientists, cognitive scientists, physicists and mathematicians interested in how biological systems compute.

Approach:
The meeting consists of three parts: a day of tutorials, three days for the main meeting, and two days of workshops. Sessions currently planned for the first day include presentations on numerical simulation techniques, a review of general purpose simulators, and methods for imaging network activity in the nervous system. Presentations at the main meeting are to be selected from the large number of abstracts submitted, by a committee of experts. It is anticipated that 300 to 400 scientists will attend the meeting and 75 the workshops.

TITLE: Grammars and Neural Networks for Multilevel Vision

PRINCIPAL INVESTIGATOR: Eric Mjolsness
Yale University
Department of Computer Science
(203) 432-1223

R&T PROJECT CODE: a44h010 CONTRACT NO:

Objective:
The objective is to develop a vision system which is a hybrid of visual grammar rules and a neural network implementation.

Approach:
Learning algorithms will be found for visual grammars and means of implementing them in neural nets. The networks will be hierarchical and will use gradient descent annealing at multiple time scales. A neural net compiler will be developed in order to manipulate visual grammars algebraically. Models of visual object rendering and SAR imagery will be formulated as rules in a visual grammar with a corresponding neural net. The visual grammar approach will be combined with 3D modeling.

Progress:
This grant is new in FY92.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Computational Models of Olfactory and Spatial Cognition

PRINCIPAL INVESTIGATOR: Lynn Nadel
University of Arizona
Division of Psychology
(602) 626-2615

R&T PROJECT CODE: 442h025 CONTRACT NO: N0001490J1869

Objective:
A 48 element stereotrode array will be used to simultaneously record from about 150 differentiable cells in layer CA1 of the hippocampus as the rats perform a learned task involving their knowledge of spatial location. This data will be modelled and tested against a hypothesis that explains the process whereby the nervous system accomplishes this task.

Approach:
This work represents an empirical investigation of the Hebb-Marr hippocampal network theory using massively parallel recording from conscious animals. The PIs will determine whether the field potentials generated during exploration are specific to a given context (familiar vs. unfamiliar) and whether these potentials change as the system stores information about new environments. The prediction of the Hebb-Marr formalism is representational stability in contrast to several connectionistic schemes based on competition which would predict representational instability.

Progress:
PI provides excellent evidence that LTP or long-term enhancement produced by nitric oxide in vitro does not reflect the same process as LTP induced in the intact brain. PI also demonstrates a change in gene expression of a protein whose phosphorylation was previously shown to be significantly changed after LTE.

Report:
Barnes, C.A., McNaughton, B.L., Bredt, D.S., Ferris, C.D. and Snyder, S.H. (1992). Nitric oxide synthetase inhibition in vivo: lack of effect on hippocampal synaptic enhancement or spatial memory. Science. (In press).

TITLE: Dynamical Cognitive Systems

PRINCIPAL INVESTIGATOR: Jordon B. Pollack
Ohio State University
Laboratory for AI Research
(614) 292-4890

R&T PROJECT CODE: 4426525 CONTRACT NO: N0001492J1195

Objective:
The objective is to explore how symbolic models and formal languages can arise from neural networks exhibiting complex non-linear dynamics.

Approach:
In order to clarify the mapping between biological and connectionist systems, theories will be developed of how the complex dynamics discovered in neural circuitry can be exploited for representation, and how to link phase transitions and CPG's into concrete cognitive facilities. The PI will continue to develop the mathematics of the mapping between higher order recurrent neural networks, dynamical systems, and automata. Another major focus will be to establish the utility of the dynamical approach by construction of working connectionist prototypes for several problem areas in AI: the signal to symbol problem, symbolic retrieval (indexing) problem, and reconstructive memory for visualization.

Progress:
Demonstrated that when a recurrent higher-order neural net learns a meta-language sequence, the values of the output units exhibit a chaotic attractor with correlation dimension 1.4. Developed a fractal reconstructive memory based on recurrent nets which regenerates images.

Report:
Pollack, J.B. (1991). The induction of dynamical recognizers. Machine Learning, 7, 227-252.

TITLE: Learning Techniques for Computer Vision

PRINCIPAL INVESTIGATOR: Tomaso A. Poggio
Massachusetts Institute of Technology
Artificial Intelligence Laboratory
(617) 253-3866

R&T PROJECT CODE: a44e020 CONTRACT NO:

Objective:
The objective is to develop a machine vision system capable of learning objects in an unstructured environment.

Approach:
Learning techniques based on regularization networks will be further developed. New optimization algorithms for learning will be refined and implemented on a Connection Machine. These new techniques will be applied to 3D object recognition, including the development of techniques for the automatic recognition of models from a small number of 2D images, and applications in visual inspection and face recognition.

Progress:
Developed a theory of regularization networks. Proved that there exist classes of functions that can be approximated by a neural network of n radial units with an L_2 error of order $O(n^{-\frac{1}{4}})$. Showed that for normalized inputs, multilayer perceptron nets are equivalent to radial function nets. Developed a theory of brain function based on modules for multivariate function approximation realized as hyperbasis function nets. Constructed networks built using the hyperbasis function technique, compared the results to human psychophysical studies, and evaluated them on 3D object recognition and time series analysis problems.

Report:
Edelman, S. and Poggio, T. (1991). Models of object recognition. Current Opinion in Neurobiology, 1, 270-273.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Reconstructing Computational Principles in a Dynamic Controller in the Brain

PRINCIPAL INVESTIGATOR: James S. Schwaber
E.I. du Pont de Nemours & Company, Inc.
Neural Computation Program
(302) 695-7136

R&T PROJECT CODE: 4426455 CONTRACT NO:

Objective:
The objective is to develop models and controller architectures derived from neurobiological experiments which will perform hierarchical nonlinear control.

Approach:
Both in vitro and in vivo experiments will be performed on brainstem control of the baroreceptor reflex. Neuronal types and characteristics will be determined under voltage-clamp and current-clamp and in response to synaptic inputs. The same neuron types will be recorded during system behavior and during external perturbation. Single neuron and network models will be built and analyzed in order to capture both the neuronal and system dynamics. The emergence of systems function from the computational properties of the neurons and the network will be explored. Features of the biological model will be abstracted in order to apply them to the design of selected multiple input/ multiple output control systems.

Progress:
The contract is new in FY92.

TITLE: Data Base Acquisition for Computational Modeling

PRINCIPAL INVESTIGATOR: Allen I. Selverston
University of California, San Diego
Department of Biology
(619) 534-2672

R&T PROJECT CODE: 4426128 CONTRACT NO: N0001491J1720

Objective:
The goals of the proposed research are to obtain physiological data from an invertebrate nervous systems which can be used to support the development of new computational models of neural functioning. These can serve as the basis for pattern recognition and motor control algorithms. Data will be obtained relating the various conductances present in single neurons to their individual information handling capabilities. Additional information will be obtained on synaptic and network properties which could be used in modelling the system.

Approach:
The model consists of only thirty neurons yet generates two complex output patterns. Moreover, these neurons are individually identifiable And their pattern of synaptic connectivity is stereotyped and well characterized. It is easy to record intracellular potentials in these neurons, including synaptic potentials. The behavior of the entire system can be altered by injecting current into single cells or by the application of various neuromodulators which alter synaptic strengths. This model system is perhaps the best understood biological pattern generator and is well suited to a quantitative analysis.

Progress:
The PI has formulated a model in which small central pattern generators (CPGs) are simulated using cellular conductances. The model has been described mathematically and is the basis for a back-propagation style of representation. The PI has also demonstrated a cellular basis for generating specific motor patterns in the presence of a neuromodulator.

Report:
Elson, R.C. and Selverston, A.I. (in press). Mechanisms of gastric rhythm generation in the isolated stomatogastric ganglion of spiny lobsters: Bursting pacemaker potentials, synaptic interactions, and muscarinic modulation. Journal of Neurophysiology.

TITLE: Optical Imaging of the Dynamics of Cortical Circuits

PRINCIPAL INVESTIGATOR: David W. Tank
AT&T Bell Laboratory
Biological Computational Research Department
(908) 582-7058

R&T PROJECT CODE: 442h021 CONTRACT NO:

Objective:
Objective is to develop functional models of the adult cerebral cortex and to characterize spontaneous and evoked circuit dynamics.

Approach:
Optical recording combined with careful stimulation paradigms will provide a powerful approach for the functional mapping of cortical circuits, permitting the assessment of inputs and outputs of identified populations of cells to determine the details of the modular architecture.

Progress:
This contract is new in FY92.

TITLE: A Biological Neural Network Analysis of Learning and Memory

PRINCIPAL INVESTIGATOR: Richard F. Thompson
University of Southern California
Department of Psychology
(213) 743-2240

R&T PROJECT CODE: 4426001 CONTRACT NO: N0001491J1392

Objective:
A two year research plan includes three levels of complexity within which the PI plans to model the critical neuronal circuitry; each level builds cumulatively on the previous levels. Level I concentrates on single pathway models of conditioning involving the IO, deep nuclei, and other brain structures. These models will address phenomena at a trial-level of detail comparable to the Rescorla-Wagner model. Level II integrates level I into real-time models of conditioning which address effects of ISI manipulations and adaptive delay of the CR. Level III incorporates the previous levels into multiple-pathway models involving more complete descriptions of the stimulus-response pathways.

Approach:
Approach involves a detailed empirical characterization of the properties of the essential neurobiological network and a quantitative computational modeling of the network that incorporates all the known properties and constraints of the actual biological network.

Progress:
Current modeling work focuses on conditioned stimulus representations in classical conditioning to account for conditioned response topography. Current empirical work has demonstrated that cerebellar lesion abolition of conditioned learned skilled movements is due to damage to the memory trace system and not to effects on performance, and has explored the role of auditory cortex in the learning of elementary skilled movements.

Report:
Knowlton, B.J. and Thompson, R.F. (1992). Conditioning using a cerebral cortical CS is dependent on the cerebellum and brainstem circuitry. Behavioral Neuroscience, 106, 509-517.

TITLE: Computer Simulation of Neural Systems

PRINCIPAL INVESTIGATOR: Thomas P. Vogl
Environmental Research Institute of Michigan
(703) 528-5250

R&T PROJECT CODE: 4426132 CONTRACT NO: N0001492C0018

Objective:
The technical objectives involve finding the answers to the following questions related to Dr. Alkon's model:

(1) What are the roles of presynaptic, postsynaptic, and intraneural time delays in biological network performance and stability? (2) Which features of the biologic system are essential for the memory/recognition process and which are phylogenetic detritus? (3) What are the qualitative and quantitative differences between long- and short-term memory? (4) What is the role of changes in the membrane potential curves (membrane polarization) in the learning process? (5) What are the respective roles of pan-neurons vs. circum-synaptic membrane changes in the learning and recall processes? (6) What is the role of interlayer, particularly next-nearest-neighbor layer, connections in the performance of neural nets?

Approach:
Initially, efforts will focus on modelling the structure, neurochemistry, neurophysiology, and biophysics of the marine mollusc Hermissenda crassicornis with eventual extension to more complex, vertebrate systems. An essential feature of the proposed effort will be the close collaboration among neurophysiology and biophysics researchers at the National Institutes of Health (DHHS/NIH/NINCDS) and computer science and applied mathematics researchers at ERIM in all stages of the planning and execution of the research.

Progress:
PI has developed a description of associative memory formation and retrieval in biological systems derived from neurophysiological experiments. This neural network with non-Hebbian synapses (DYSTAL) has been applied with success to recognizing hand-printed kanji characters and face recognition.

Report:
Alkon, D.L., Blackwell, K.T., Vogl, T.P. and Werness, S.A. (1992). Biological plausibility of artificial neural networks: learning in non-Hebbian synapses. Associative Neural Memories, M.H. Hassoun, ed., Oxford University Press.

TITLE: Analysis of Neural Network Issues; Temporal Pattern Recognition, Integration with Fuzzy Logic

PRINCIPAL INVESTIGATOR: Gregg Wilensky
R & D Associates
(213) 645-1122

R&T PROJECT CODE: a44f004 CONTRACT NO: N0001489C0257

Objective:
The objective is to explore the scaling issues of neural networks for both static pattern classification problems and the classification of temporally varying signals. Another objective is to assess the utility of combining neural networks with fuzzy logic.

Approach:
The approach will involve implementations of neural nets and assessing their ability to scale up for pattern classification tasks. An integrated fuzzy logic neural net will be developed to determine the probabalistic functions which minimize overall error on control and classification problems. The PI will collaborate with R. Granger (UCI) to explore the capabilities of a new temporal sequencing model based on neural dendrite properties. The performance of this model will be compared with other neural nets on test problems, and evaluated, based on code development time, speed of operation, learning rate, and performance of correct classifications. Neural net approaches will also be evaluated on an industrial process control problem.

Progress:
The investigator has developed a new projection neural net which provides fast training and error minimization. The method involves forming either closed (hyperspherical) or open (hyperplane) prototypes. Input vectors are projected on higher dimensional hyperspheres, and hyperplanes in the higher dimension correspond to hyperspheres or hyperellipses in the original input space. A hierarchical neural net was also tested on SAR imagery and found to outperform humans in low SNR conditions.

Outside Funding:
Funds for this project are provided by DARPA.

BIOLOGICAL INTELLIGENCE

SINGLE-NEURON COMPUTATION

TITLE: Theoretical and Experimental Determination of the Biological Mechanism of Retinal Directional Selectivity

PRINCIPAL INVESTIGATOR: Franklin R. Amthor
University of Alabama
Department of Psychology
(205) 934-2694

R&T PROJECT CODE: 4426610 CONTRACT NO: N0001491J1280

Objective:
The objective is to determine the computational algorithms and synaptic circuitry underlying sensitivity of retinal neurons to direction of motion of visual targets.

Approach:
The fundamental approach of the proposed research is to combine formal, theoretical analysis with physiology and quantitative anatomy. Analyses will employ linear and nonlinear filtering methods based on 2-D Fourier transforms of the visual stimulus. transforms of the visual stimulus.

Progress:
Initial work has been concerned with quantifying the inhibitory and facilitative mechanisms in retina with respect to spatial and temporal extent. A series of 2 spot apparent motion experiments has been conducted. Using a base subtraction procedure, they found that inhibitory interations tend to be long lasting, act over long distances, are segregated by sign of contrast, and are spatially asymmetric. This interaction is nonlinear, and has been modelled as a divisive function. Facilitative interactions have much shorter time courses, and act over shorter distances.

Reports:
Amthor, F.R. and Grzywacz, N.M. (1992). Inhibition in On-Off directionally selective ganglion cells in the rabbit retina. J. Neurophysiol., in press.

TITLE: Self-Organization of Hebbian Synapses on Hippocampal Neurons

PRINCIPAL INVESTIGATOR: Thomas H. Brown
Yale University
Department of Psychology
(203) 432-7009

R&T PROJECT CODE: 4426405 CONTRACT NO: N0001490J4136

Objective:
The objective is to discover the computational capabilities of single hippocampal neurons containing Hebbian synapses using realistic simulations based on data obtained by electrophysiology and anatomical imaging techniques.

Approach:
The general approach involves constructing model hippocampal neurons and then embedding them in environments that consist of different types of spatiotemporal correlations among the synaptic inputs. There will be continuous interaction between simulations and experimental analysis. Morphological data on neurons will be obtained by accurate 3-D reconstruction of dendritic surface from images obtained by confocal laser scan microscopy. Physiological data will be obtained by whole-cell patch clamp recording, and use of voltage or Ca++ sensitive dyes.These data will be incorporated in a detailed compartmentai electrotonic model.

Progress:
A single neuron simulator has been developed which accepts morphometric data, has 3-D graphics output and is able to code any variable of interest, such as voltage or synaptic strength. The simulator is based on the algorithms of Heinz's NEURON package. A detailed spine model has been completed, and whole-neuron models have been developed. Self-organization of synaptic inputs on passive dendrites has been studied. The dendritic spines show "feature clusters" in synaptic weights based on spatio-temporal correlations in the inputs. Hence neurons become tuned to different features.

Reports:
Brown, T.H., Zador, A. and Claiborne, B. (1992). Hebbian computations in hippocampal dendrites and spines. In: Single Neuron Computation, T. McKenna, J. Davis, and S. Zornetzer, Eds., Academic Press, 81-116.

TITLE: Neuronal Micronets as Nodal Elements

PRINCIPAL INVESTIGATOR: Thomas H. Brown
Yale University
Department of Psychology
(203) 432-7008

R&T PROJECT CODE: a44e015 CONTRACT NO:

Objective:
The objective is to understand the differences between computations performed in real neurons and the processing elements of neural nets, and to develop a micronet architecture which captures the computations in neurons.

Approach:
Simulations will be conducted of the clustering of active synapses on dendrites in the case of linear membrane and examine the mechanisms that limit the growth of synaptic strength. Realistic simulations of neurons with nonlinear membrane will be performed in order to understand the self-organization and nonlinear pattern separation of synapses on dendrites. A neural network will be developed with the self-organizing properties of model neurons and realistic model neurons will be embedded into recurrent network architectures based on the hippocampus.

Progress:
Demonstrated that the electrotonic structure of the neuron is a primary constraint on the self-organizing pattern of synaptic welights for Hebbian synapses. Showed that spatial structures of functionally related synapses become strengthened and that this spatial clustering leads to nonlinear pattern separation when combined with membrane nonlinearities known to be present in real neurons. Demonstrated that individual dendritic branches are capable of the XOR (exclusive-or) operation.

Report:
Zador, A., Claiborne, B. and Brown, T. (1992). Nonlinear pattern separation in single hippocampal neurons with active dendritic membrane. In: Advances in Neural Information Processing Systems. San Mateo, CA: Morgan Kaufmann, Vol. 4, 51-58.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Cooperative Stochastic Effects in Single Neuron Models

PRINCIPAL INVESTIGATOR: Adi R. Bulsara
Naval Ocean Systems Center
(619) 553-1595

R&T PROJECT CODE: 442n006 CONTRACT NO: N0001492WX24238

Objective:
The objective is to characterize the role of noise in single neuron, and multi-neuron information processing.

Approach:
The role of intrinsic and extrinsic noise on the spike interval code of neuron models will be examined for the case of bistable potentials corresponding to a transfer function described by a hyperbolic tangent. the model output will be compared with real neural data, and the models fine tuned by restricting the noise spectra. Stochastic resonance phenomena will be explored for a reduced neuron model, and simple networks of model neurons.

Progress:
For a network of neurons subject to Langevin and multiplicative noise, they derived the closed-form dynamics of a single reference neuron and its interaction with the remaining neurons. Stochastic resonance was investigated in the reduced dynamics, and it was shown that coupling to the "dendritic bath" could lead to larger signal to noise ratio at the cell body output.

Report:
Bulsara, A. and Schiere, W. (1992). The single effective neuron: macroscopic potential and noise-induced bifurcations. Physical Review, A., in press.

TITLE: Models of Biophysical and Biochemical Processes Contributing to Computations and Information Processing in Single Neurons

PRINCIPAL INVESTIGATOR: John H. Byrne
University of Texas
Department of Neurobiology and Anatomy
(713) 792-5702

R&T PROJECT CODE: 442n101 CONTRACT NO: N0001492J1152

Objective:
The objectives are (a) to examine the control of dynamic pattern generation in single model neurons by synaptic currents and to (b) combine electrotonic models with second-messenger cascades in order to evaluate the role of such biochemical mechanisms on neural computation.

Approach:
A detailed, quantitative model of a single neuron, which reflects properties of the R15 bursting neuron in Aplysia, will be developed, and the computational capabilities of the resultant model will be examined. This analysis will build upon previous Hodgkin-Huxley type models which simulate the chaotic bursting and beating modes of endogenous activity of R15 neurons. Second messenger biochemical cascades, realistic synaptic currents, and modulator chemical inputs will be incorporated to examine the physiological and computational interaction of these realistic neuronal features.

Progress:
Simulations demonstrated that synaptic currents appear to not only induce shifts to chaotic behavior in neurons, but also induce shifts to a wide spectrum of distinct modes of activity, each with a distinct attractor. A set of nested attractors is characteristic of each neuron, and the geometric relationship of these attractors provides a mechanism for temporal specificity.

TITLE: Diverse Computational Properties of Single Neurons in Neocortex

PRINCIPAL INVESTIGATOR: Barry W. Connors
Brown University
Division of Biology and Medicine
(401) 863-2982

R&T PROJECT CODE: 4426402 CONTRACT NO: N0001490J1701

Objective:
The objective is to examine the computational properties of different types of single neocortical neurons quantitatively.

Approach:
The approach is to record from single cortical neurons in vitro, subjected to a variety of standardized protocols to determine their firing patterns in response to specified inputs, and identify the neuron morphology by dye injection. The effects of the neuromodulators norepinephrine and acetylcholine on the transform properties of different types of neurons will be examined quantitatively. In order to test the hypothesis that different intrinsic input-output properties of single neurons are significant for network behavior, a formal model of a net of realistic model neurons will be developed. This study will explore the importance of intrinsic neuronal properties in biological models of neocortex.

Progress:
Cells were recorded intracellularly in slices and filled with dyes, measured and reconstructed as compartmental models using Neuron or Genesis. Nonpyramidal neurons and smaller upper layer pyramidal neuron were found to be electrotonically compact. The apical dendrites of deep pyramidal neurons were predicted to be electronically long if passive membrane is assumed. However, physiological measurements contradict this, and these dendrites were found to have voltage-dependent calcium conductances.

Report:
Cauller, L.J. and Connors, B.W. (1992). Functions of very distal dendrites: Experimental and computational studies of layer I inputs to layer V pyramidal neurons in neocortex. In: Single Neuron Computation, T. McKenna, J.Davis & S. Zornetzer, Eds, Academic Press, 199-229.

TITLE: Controlled Growth and Communication in Defined Patterns of Neurons

PRINCIPAL INVESTIGATOR: Thomas L. Fare
Naval Research Laboratory
(202) 767-4302

R&T PROJECT CODE: 4426510 CONTRACT NO: N0001492WX24069

Objective:
The objectives are to (1) determine the adhesive and morphological properties of neural cells on high resolution photolithographic patterns of ultra thin films, (2) determine optimum protocols for geometric definition of synapse formation, (3) study the synaptic potentials resulting from different input configurations, and (4) relate the data to neural models.

Approach:
Alternating patterns of ultra thin films (UTF) will be prepared on glass substrates by self-assembly and ablation with deep ultraviolet radiation through metallized masks. Patterns of silane-coupled ethylendiamine and tridecaflurene, and/or laminin fragments and glial cells will be used to promote adhesion of explanted neurons. Neurons will be stimulated with substrate-mounted electrodes, and responses recorded using intracellular microelectrodes.

Progress:
A dedicated excimer laser and mask aligner were installed and special masks for defining neuronal networks were developed. Hippocampal neurons were cultured on EDA and 13F silane patterns. Haparan sulfate was found to absorb preferentially to EDA and is being examined for tissue patterning. A derivative of EDA was shown to require 100 times less radiation energy for photolysis, opening the possibility of non-laser light sources for UV photolithography.

Report:
Dulcey, C.S., Georger, J.H., Drauthamer, V., Stenger, D.A., Fare, T.L. and Calvert, J.M. (1991). Deep UV photochemistry of chemisorbed monolayers: patterned coplanar molecular assemblies. Science, 252, 551-554.

TITLE: Simulation of Excitatory/Inhibitory Interactions in Single Auditory Neurons

PRINCIPAL INVESTIGATOR: Don H. Johnson
Rice University
Department of Electrical & Computer Engineering
(713) 527-4820

R&T PROJECT CODE: 4426433 CONTRACT NO: N0001492J1558

Objective:
The investigators will examine the fundamental interactions between excitatory and inhibitory point processes in auditory neurons.

Approach:
Computer simulations will be made of the interaction of trains of excitatory and inhibitory synaptic inputs on Lateral Superior Olive (LSO) neurons of the brainstem. Simulation results will be analyzed using sensitive point process techniques which the investigators have developed and compared with similar analyses applied to actual LSO neuron recordings. The simulation vehicle will be the GENESIS simulator, with enhancements for histogram generation, support for long term simulations and simplified models for the generation of LSO input patterns.

Progress:
This grant is new in FY92.

TITLE: Understanding Cortical Microcircuits: A Combined Anatomical, Physiological, Computational and Electronic Approach

PRINCIPAL INVESTIGATOR: Christof Koch
California Institute of Technology
Computation & Neural Systems Program
(818) 356-6855

R&T PROJECT CODE: 4426410 CONTRACT NO: N0001491J1452

Objective:
The objective is to specify the neuronal properties and connections of a basic cortical circuit that will exhibit some of the important visual response properties of real cortex, and to render this circuit in analog VLSI.

Approach:
Microscopic data will be used to reconstruct the detailed morphology of labelled neurons in the visual cortex of cat. These reconstructions, and their associated physiological data, will provide the biological basis for realistic simulations. Detailed computer simulations based on solution of associated nonlinear cable and diffusion equations of these real neurons will be constructed. The dynamic properties of small microcircuits composed of three types of neurons, referred to as the "Canonical Microcircuit" will be investigated with sensory inputs. A range of CMOS VLSI subcircuits and networks, using pulse coding, will be designed and fabricated as powerful modelling tools for linking the properties of visual cortex with the real neuron microcircuitry.

Progress:
The electrical behavior of an anatomically reconstructed cortical pyramidal cell receiving input from 4000 excitatory and 1000 inhibitory neurons firing spontaneously was simulated. Membrane time constant and input resistance were observed to change by a factor of 10 over the range of spontaneous activity. Thus global activity in the network can control how individual cells perform spatial and temporal integration.

Report:
Bernander, O., Douglas, R., Martin, K. and Koch, C. (1992). Synaptic background activity determines spatio-temporal integration in single pyramidal cells. Proceedings of the National Academy of Science.

TITLE: Intermittency, Neuronal Coding, and Neurophysiological Computational Neural Network Design

PRINCIPAL INVESTIGATOR: Arnold Mandell
Florida Atlantic University
Department of Mathematics
(407) 367-3358

R&T PROJECT CODE: 4426535 CONTRACT NO: N0001492J1531

Objective:
The objective is to analyze single neuron and global neural recordings using new measures derived from the ergodic theory of dynamical systems and to perform theoretical studies on neural coding schemes.

Approach:
Analysis will be made of the discharge patterns of neurons in brain stem aminergic cell groups and the EEG of the hippocampus using measures derived from dynamical systems theory. These analytical tools will also be applied to the hidden layers of biological and artificial neural networks, and theoretical studies conducted on the topological, orbital, and statistical equivalence relations between real and computational middle layers. Based on this dynamical system analysis new computational networks will be designed which incorporate selected features of the real neuron dynamics.

Progress:
In neural models, demonstrated that dwell times in regions of inverse saddle sink intermittency (bursting) and homoclinic tangencies are increased by white and colored noise in global neural membrane membrane equations studied at the appropriate parameter values. Broadening of the unstable manifold by inhibiting noise can regulate the time spent between firings and therefore ISI distributions. These qualitative dynamical phenomona can also be demonstrated in real neural data.

Report:
Selz, K. and Mandell, A. (1992). Bursting intermittency and microwave popcorn's comments on the "reporting out" of neuron-like firing behavior. In: NATO ARW on Growth Patterns in Physical Sciences and Biology, (P. Meakin, Ed.) in press.

TITLE: Computational Capabilities of Hippocampal Neurons

PRINCIPAL INVESTIGATOR: John P. Miller
University of California, Berkeley
Department of Cell and Molecular Biology
(415) 642-9045

R&T PROJECT CODE: 4426403 CONTRACT NO: N0001490J1879

Objective:
The objective is to determine the computational capabilities of hippocampal neurons by creating realistic computer models of hippocampal neurons and their synapses.

Approach:
Realistic compartmental models of hippocampal neurons will be produced which represent neurons as a network of equivalent electrical circuits. The models will be based on functional reconstructions that combine both morphological and physiological characteristics of dendrites as well as biophysical representations of synapses. Three dimensional reconstructions of granule neurons will be produced with a computer-microscope digitization system. This system will be extended to utilize a high resolution confocal microscope. Accurate measurements of biophysical parameters, including the synaptic currents for NMDA and non-NMDA synapses will be obtained from patch-clamp recordings.

Progress:
The investigators have made precise measurements of the passive and active membrane properties of neuron dendrites, morphologically reconstructed these neurons, and incorporated these electrical and morphological measurements into computer models of the neurons. The models were then used to investigate the computational properties of the neurons. The limits of resolution with which different patterns of synaptic input could be resolved by the model neurons was characterized in a model-independent manner, using the principles of information theory. In order to obtain more accurate morphological data from neurons using confocal microscopy, a technique combining fluorescent labels and HRP injection into the same neuron has been developed.

Report:
Claiborne, B.J., Mainen, Z.F., Zador, A.M. and Brown, T.H. (1992) Computational models of the principal classes of hippocampal neurons. In: Single Neuron Computation, T. McKenna, J. Davis, S. Zornetzer, Eds., Academic Press, 61-80.

TITLE: Understanding Cortical Microcircuits: A Combined Anatomical, Physiological, Computational and Electronic Approach

PRINCIPAL INVESTIGATOR: Kevan A. Martin
Medical Research Council
Department of Pharmacology
448-6527

R&T PROJECT CODE: 4426411 CONTRACT NO: N0001491J1830

Objective:
The objective is to specify the neuronal properties and connections of a basic cortical circuit that will exhibit some of the important visual response properties of real cortex, and to render this circuit in analog VLSI.

Approach:
Microscopic data will be used to reconstruct the detailed morphology of labelled neurons in the visual cortex of cat. These reconstructions, and their associated physiological data, will provide the biological basis for realistic simulations. Detailed computer simulations based on solution of associated nonlinear cable and diffusion equations of these real neurons will be constructed. The dynamic properties of small microcircuits composed of three types of neurons, referred to as the "Canonical Microcircuit" will be investigated with sensory inputs. A range of CMOS VLSI subcircuits and networks, using pulse coding, will be designed and fabricated as powerful modelling tools for linking the RF and feature extraction properties of visual cortex with the real neuron microcircuitry.

Progress:
This grant is new, but initial collaboration between Rodney Douglas and Misha Mahowald has produced a novel silicon neuron which emulates the electrophysiological characteristics of real neurons. A patent application has been filed.

Report:
Douglas, R. and Martin, K. (1992). Exploring cortical microcircuits: A combined anatomical, physiological, and computational approach. In: Single Neuron Computation, T. McKenna, J. Davis, S. Zornetzer (Eds.), Academic Press, 381-412.

TITLE: Noise Induced Information Flow in Neurons: A Search for Stochastic Resonance Effects in Neurons

PRINCIPAL INVESTIGATOR: Frank Moss
University of Missouri
Department of Physics and Biology
(314) 553-6150

R&T PROJECT CODE: 4426527 CONTRACT NO: N0001492J1235

Objective:
The objectives are to understand the role of stochastic process in sensory processes, and to obtain evidence for stochastic resonance phenomena in neurobiological systems.

Approach:
The approaches include: (a) construction of theories, involving solutions of stochastic PDE's, and to (b) test them numerically and with analog and digital simulations of excitable system models, including H-H and FitzHugh-Nagumo models, to explore stochastic resonance effects and to generate interspike interval histograms for comparison to those obtained experimentally. (c) Experimental data will be obtained from hair mechanoreceptors and nerve roots of crayfish. A range of stimulus frequency, intensity, and noise signals will be provided to these receptors. Additional ISI data will be provided by Dr. Ralph Siegal at Rutgers from monkey cortex.

Progress:
Preliminary tests of the stochastic resonance hypothesis are underway in crayfish mechanoreceptor neurons. Changes in internal noise are produced by varying the temperature. The model has also been tested against data from auditory nerve. The well residence-time probability distributions of the bistable model were found to exhibit the main features of the interspike interval histograms of these neurons.

Report:
Longtin, A., Bulsara, A. Pierson, D. and Moss, F. (1992). Bistability and the dynamics of periodically forced sensory neurons, submitted: Biophysical Journal.

TITLE: Role of Spatially Distributed Ion Channels in Single Neuron Computations

PRINCIPAL INVESTIGATOR: Peter C. Schwindt
University of Washington
Department of Physiology and Biophysics
(206) 543-6310

R&T PROJECT CODE: 4426401 CONTRACT NO: N0001490J1627

Objective:
The technical objective is to gain a detailed understanding of the computational ability of a single cortical neuron.

Approach:
Single neuron computation is likely to depend in part on the properties of voltage-gated channels located on the dendritic membrane. Such channels are known to exist, and are thought to be important in neural function, but almost no information is available on their precise spatial distribution or electrical properties. The investigators propose to measure the spatial distribution and electrical properties of specific ion channels in the soma-dendritic region of cortical neurons. Based on these measurements, a mathematical, computer-based model of a cortical neuron will be constructed and analyzed to determine how the spatially distributed channels affect information transfer through the neuron.

Progress:
Type II sodium channels, which are restricted to neuron soma in cortex, were found to exhibit two modes of gating, a noninactivating mode, and a transient mode. Type III sodium channels were localized to the somata of neurons in deep layers of cerebral cortex. Preliminary results indicate that P and N type calcium channels occur at high density in the dendrites of specific neurons.

Report:
Schwindt, P. (1992) Ionic currents governing the input-output relations of Betz cells. In: Single Neuron Computation., T. McKenna, J. Davis, S. Zornetzer, Eds., Academic Press, 235-258.

TITLE: A Study of Neuronal Properties, Synaptic Plasticity and Network Interactions

PRINCIPAL INVESTIGATOR: David Tam
Baylor College of Medicine
Division of Neuroscience
(713) 798-3100

R&T PROJECT CODE: 4426400 CONTRACT NO: N0001490J1353

Objective:
The objective is to investigate principles of synaptic interactions, in particular the relation of membrane properties of neurons to synaptic plasticity in groups of interacting neurons, as the substrates of learning and memory.

Approach:
The approach is a combined theoretical and experimental analysis of the biophysical properties of hippocampal pyramidal neurons. Realistic simulations of these neurons will permit the study of changes in signal processing when membrane properties are changed. The emergent properties exhibited by groups of interacting neurons, with specific synaptic plasticity rules, will be examined in computer reconstructions.

Progress:
A neural simulation program MacNeuron has been implemented on a Mac IIsi with an extensive user interface. Progress has been made in the building of networks of neurons via a menu-driven windowing interface, and a "script" description of commands for batch-mode operation. The construction of neurons is based on a top-down approach, where a hierarchy of network, neuron, membrane, ion channel, chemical concentration/compartment is followed.

Reports:
Tam, D.C. (1992). Signal processing in multi-threshold neurons. In: Single Neuron Computation (T. McKenna, J. Davis, and S.F. Zornetzer, ed.) Academic Press, 481-501.

TITLE: The Role of Dendritic Excitability in Processing Synaptic Inputs: A Combined Physiological, Morphological and Computational Study

PRINCIPAL INVESTIGATOR: Idan Segev
Hebrew University
Department of Neurobiology
02-585-100

R&T PROJECT CODE: 4426406 CONTRACT NO: N0001491J1350

Objective:
The objective is to elucidate the basic principles that govern the integrative functions of the dendrites of cerebellar Purkinje neurons.

Approach:
A combined modeling and experimental study of Purkinje cells will be conducted. Real morphological and biophysical parameters will be incorporated into realistic, large scale simulations of individual neurons and the models predictions will be tested by in vitro physiological experiments. The simulations will be enhanced by the development of new flexible algorithms which will permit modeling large numbers of realistic dendritic spine compartments. Multiple synaptic inputs will be examined in vitro by electrical stimulation or iontophoresis of neurotransmitters.

Progress:
In computer simulations the parallel fiber inputs onto Purkinje cells were shown to strongly modulate the membrane conductance, time constant and electrotonic structure of the neurons. This implies that several hundred parallel fiber inputs will be required to fire the neuron in vivo, and that the electrotonic structure is under dynamic control.

Report:
Segev, I., Rapp, M., Manor, Y. and Yarom, Y. (1992). Analog and digital processing in single nerve cells: dendritic integration and axonal propagation. In: Single Neuron Computation (T. McKenna, J. Davis and S. Zornetzer, eds.) Academic Press, 173-198.

TITLE: Enabling Technologies for Controlled Growth and Communication of Cultured Mammalian Neurons

PRINCIPAL INVESTIGATOR: David Stenger
Naval Research Laboratory
(202) 767-0724

R&T PROJECT CODE: 4426451 CONTRACT NO: N0001492WX24229

Objective:
The objective of the conference is to develop an interdisciplinary approach to the design of devices, methods, and experiments to control and interface with neuronal circuits designed in tissue culture.

Approach:
Experts will address the following technical approaches at this conference: (1) Controlled survival and physiological status of dissociated mammalian neurons, (2) geometrical definition of simple neuronal circuits, (3) improved non-invasive stimulation and recording methods, (4) experimental design for testing of computational neuroscience principles.

TITLE: Models of the Processing of Acoustic Stimuli in Stellate Cells of the Antero-Ventral Cochlear Nucleus

PRINCIPAL INVESTIGATOR: Raimond L. Winslow
The Johns Hopkins University
Whitaker School of Engineering
(301) 550-5090

R&T PROJECT CODE: 4426511 CONTRACT NO: N0001492J1134

Objective:
The objective is to develop a biophysically detailed computer model of cochlear nucleus stellate neurons in order to test theories of how these neurons might perform a sound level dependent selective processing of auditory nerve inputs.

Approach:
Biophysical data will be obtained from voltage-clamp recordings of stellate neurons within in vitro slices from guinea pig AVCN. Kinetic data on voltage dependent currents will be incorporated into a computational model of these neurons, with excitatory and inhibitory synaptic inputs distributed according to a hypothesis developed by the PI. The ability of this model to account for the receptive field and response properties of the neurons will be determined, and population models developed to simulate responses to vowel stimuli as a function of sound level.

Progress:
An equivalent cylinder model of AVCN stellate neurons has been developed and tested. A new technique for staining cochlear neurons using L toxin has been successfully implemented and a library of fully stained neurons is being developed. Preliminary voltage-clamp data have been obtained from dissociated stellate neurons.

BIOLOGICAL INTELLIGENCE

SYNAPTIC PLASTICITY

TITLE: Chemical Sensor for Microscopic Mapping of Synaptic Glutamate

PRINCIPAL INVESTIGATOR: Mark A. Arnold
University of Iowa
Department of Chemistry
(319) 335-1368

R&T PROJECT CODE: 4426268 CONTRACT NO: N0001491J1768

Objective:
To develop an analytical methodology capable of measuring in situ levels of neurotransmitters in small regions of the extracellular space in the vicinity of the synapse during neurochemical events. Primary considerations are selectivity, detection limit, spatial and temporal resolution.

Approach:
A biocatalytic-chemiluminescence reaction will be measured using an optical microscope in conjunction with a photon-counting photomultiplier (later a CCD). Efficiency of detection optics, kinetics of the reaction sequence, and mass transfer properties of the chemical species involved interrelate to control the detection limit, temporal, and spatial resolution of the method.

Progress:
A reaction sequence involving the HRP-catalyzed chemiluminescence reaction between hydrogen peroxide and luminol has been evaluated and found to provide sufficient amounts of light under reaction conditions. A mathematical model of the kinetics responsible for light generation has been developed.

Report:
Li, L., Arnold, M.A. and Dordick, J.S. (1992). Development of a biocatalytic-chemiluminescence reaction sequence for synaptic glutamate mapping. Journal of the American Chemical Society, 203, 17-19.

TITLE: Synaptic Plasticity: Neural and Molecular Approaches

PRINCIPAL INVESTIGATOR: Michel Baudry
University of Southern California
Biological Sciences
(213) 740-7762

R&T PROJECT CODE: 4426267 CONTRACT NO: N0001491J1821

Objective:
Using 3H-MK-801 as a marker for functional NMDA receptors and microdissection and quantitative autoradiographic techniques; (1) To determine the extent and localization of activated NMDA receptors under conditions leading to LTP in hippocampus. (2) To determine the distribution of activated NMDA receptors in various behavioral paradigms measuring memory capacity.

Approach:
The approach takes advantage of a labeled ligand that tags functional NMDA receptors to study the relationships between learning and the in situ functioning of NMDA receptors. 3H-MK-801 labels the open state of the Ca channel associated with NMDA and LTP. Learning paradigms include; inhibitory avoidance, Y-maze discrimination, and one trial olfactory learning.

Progress:
The PI has demonstrated increasing binding affinity for agonists of AMPA receptors producing increased synaptic responses. Furthermore, binding properties of AMPA receptors are readily modified by temperature and calcium ions, thereby providing a tool to study regulation of excitatory synapses.

Report:
Shahi, K. and Baudry, M. (1992). Effects of chaotropic ions on tritiated AMPA binding in synaptic membranes and on synaptic responses in rat hippocampal slices. Proceedings of the National Academy of Science (in press).

Tocco, G., Massiotte, G., Stendley, S., Thompson, R.F. and Baudry, M. (1992). Effects of temperature and calcium on the binding characteristics of AMPA receptors in rat brain sections. European Journal of Neuroscience (in press).

TITLE: Experimental Investigations of Synaptic Learning Rules in the Cerebral Cortex

PRINCIPAL INVESTIGATOR: Mark F. Bear
Brown University
Center for Neural Science
(401) 863-2070

R&T PROJECT CODE: 4426137 CONTRACT NO: N0001492J1410

Objective:
In the proposed experiments, the effects of high-frequency electrical stimulation of the white matter on the amplitude of cortical EP's will be studied as several parameters are varied systematically. In addition to manipulations of GABAergic inhibition, other parameters of interest will be the presence or absence of the modulatory substances acetylcholine and norepinephrine, the relative effectiveness of NMDA and non-NMDA receptors, and the effects of prior visual deprivation. The objective of these experiments is to formulate a set of rules that govern whether a burst of presynaptic activity leads to a lasting increase or decrease in synaptic strength. These rules can then be compared with the extant theoretical models of network modification.

Approach:
Synaptic modifications have been observed directly in the developing visual cortex of behaving kittens. Critical variables appear to be the presence or absence of extrathalamic modulatory inputs, the level of network inhibition, the amount of stimulus-driven excitatory presynaptic activity, the concurrent level of evoked post-synaptic depolarization, and the recent history of neuronal activity. In the proposed experiments, a reduced preparation of the visual cortex, the in vitro brain slice, will be used to elucidate the precise contributions of each of these variables.

Progress:
A direct biological test of the unsupervised BCM learning rule performed in hippocampal area CA1 determined synapse modification to be a function of input activity and post-synaptic depolarization.

Report:
Dudek, S.M. and Bear, M.F. (1992). Homosynaptic long-term potentiation of slices of kitten visual cortex and the effects on NMDA receptor blockade. Journal of Neurophysiology, 67, 841-851.

TITLE: Long-Term Potentiation: A Debate of Current Issues

PRINCIPAL INVESTIGATOR: Serge Laroche
Centre National DeLa Recherche Scientifique
Departement de Psychophysiologie
(703) 696-4504

R&T PROJECT CODE: 4426331 CONTRACT NO:

Objective:
This symposium will provide a unique opportunity to critically evaluate the existing data and hypotheses regarding Long Term Potentiation (LTP) and to reach a consensus between competing laboratories in Europe and the US on some of the most salient issues. In addition, this symposium will generate new hypotheses, theories, ideas and collaborative experiments that might otherwise take much longer to be initiated. Meeting proceedings will probably be published by MIT Press.

Approach:
A small symposium (40 participants) organized following the model of the Neuroscience Research Programs and the Dahlen conferences is an ideal forum to promote the type of exchange and interaction between European and American scientists required to clarify current issues in the LTP area. The meeting will last three days and is hosted by the French NSF equivalent.

TITLE: Fifth Conference on the Neurobiology of Learning and Memory

PRINCIPAL INVESTIGATOR: James L. McGaugh
University of California, Irvine
Center for the Neurobiology of Learning & Memory
(714) 856-5993

R&T PROJECT CODE: 4426315 CONTRACT NO: N0001490J4008

Objective:
The conference participants will examine the locus of alterations in brain activity at three levels of organization: global cerebral function, specific systems, cellular and molecular mechanisms. The proceedings will be published.

Approach:
The contractors anticipate an international participation of 350 scientists including university faculty, postdocs, graduate students and from diverse institutions including government, private, industrial and academic laboratories. The proceedings will be published.

TITLE: Cellular Mechanisms of Long-Term Depression of Synaptic Transmission and Its Role in Memory Systems

PRINCIPAL INVESTIGATOR: Patric K. Stanton
Albert Einstein College of Medicine
Department of Neuroscience
(212) 430-2574

R&T PROJECT CODE: 400x080 CONTRACT NO: N0001490J1988

Objective:
The objective is to determine the rules and mechanisms of synaptic changes during learning. Specifically, the rules governing induction of long-term potentiation and depression of synaptic strength in hippocampus, and the receptor types regulating these changes will be identified. The long term objective is to incorporate the rules for associative interactions that regulate synaptic strength into models of hippocampal function in order to generate predictions about the behavioral consequences of long-term plasticity.

Approach:
The rules and mechanisms governing synaptic plasticity will be examined in hippocampal slices. The timing rules for induction of LTD and LTP will be examined by varying the phase relation between 2 inputs. The relative duration and decay of LTD and LTP will be compared. The receptor mechanisms of LTD will be examined by applying antagonists such as AP3 and obtaining dose-response relations. Intracellular recordings will be obtained to examine the role of postsynaptic potentials in LTD. The interaction of LTD and NMDA dependent mechanisms will be examined by varying the Mg2+ ion concentration in the medium.

Progress:
The PI has collected evidence that prior enhancement of synaptic strength in a specific pathway can lower the threshold for subsequent LTD induced by presynaptic firing that is negatively correlated with postsynaptic inactivity.

Report:
Wexler, E. and Stanton, P.K. (1992) Priming of the induction of long-term depression by theta frequency synaptic activity and by long-term potentiation in the hippocampus. Submitted to Science.

BIOLOGICAL INTELLIGENCE

SENSORY NEUROSCIENCE AND SIGNAL PROCESSING TECHNOLOGY

TITLE: Spatial Coding by Posterior Parietal Neurons

PRINCIPAL INVESTIGATOR: Richard A. Andersen
Massachusetts Institute of Technology
Department of Brain and Cognitive Sciences
(617) 253-5773

R&T PROJECT CODE: 442g004 CONTRACT NO: N0001489J1236

Objective:
The objective is to deduce the coding of coordinate transformations in parietal cortex. A long standing question regarding the source of the eye position signal will be addressed by determining experimentally whether it is derived from efference copy or proprioceptive inputs. Computational models will be made progressively more complex by adding circuit details of known brain structures.

Approach:
A combination of physiological and computational techniques will be used in a series of experiments to pursue the question of how spatial transformations are accomplished in the posterior parietal cortex. The first series of experiments will determine whether head as well as eye position signals gate the visual responses of area 7a neurons, thus producing a coding for location in body-centered as well as head-centered coordinates. The second series of experiments will involve studies of 2-dimensional spatial tuning to examine the third dimension of depth by testing cells for vergence and disparity signals.

Progress:
A neural network model was developed to produce a representation of space in body-centered coordinates using head-position signals. Predictions of this model were tested in experiments in awake, behaving monkeys. The recorded data confirmed the predictions of the model.

Report:
Brotchie, P.R., Andersen, R.A. and Goodman, S. (1992). The influence of head position on the representation of space in parietal cortex. Science. (In press)

TITLE: Condition-Based Machinery Maintenance

PRINCIPAL INVESTIGATOR: Thomas W. Brotherton
Orincon Corporation
(619) 455-5530

R&T PROJECT CODE: 400e147 CONTRACT NO: N0001492C0059

Objective:
The goal of phase I is to develop and demonstrate a system that uses multiple feature extractors and a multilayer neural net to perform detection and classification of helicopter transmission data.

Approach:
Several feature extractor techniques will be chosen for processing of accelerometer data from a gearbox including instantaneous frequency time distributions. The data set will be segmented for training, and a backpropagation neural net will be evaluated as a classifier. A real time prototype of the system will be developed and evaluated on the data.

Progress:
This contract is new in FY92.

TITLE: Night Vision and Parallel Processing in the Retina

PRINCIPAL INVESTIGATOR: Richard L. Chappell
The City University of New York
Department of Biological Sciences
(212) 772-5220

R&T PROJECT CODE: 4426155 CONTRACT NO:

Objective:
The all-rod skate retina is an ideal preparation from which to obtain insight into the basic retinal processes contributing to rod-mediated vision and the pathways involved. Findings will be incorporated into models and algorithms developed to describe significant aspects of the results for applications to machine vision.

Approach:
Electrophysiological and pharmacological techniques will be used to study the membrane properties of isolated bipolar cells dissociated from the skate retina.

Progress:
This grant is new in FY92.

TITLE: Advanced Neural Network Architectures for Sonar Signal Sequences

PRINCIPAL INVESTIGATOR: Larry Deuser
Tracor Applied Sciences, Inc.
(512) 929-2047

R&T PROJECT CODE: a44e011 CONTRACT NO:

Objective:
The objectives are to develop a dynamic-in-time classifier for underwater acoustic sequence recognition and to integrate signal processing, neural networks, and AI technologies into effective decision making.

Approach:
Signal processing and feature extraction will be optimized for subevent detection. Neural networks for sequence recognition will be designed and optimized with respect to network size and noise robustness. Methods of incorporating neural nets with higher-level reasoning and uncertainty models will be investigated. This includes investigations of probabalistic and fuzzy expert classifiers for fusing information from qualitative and quantitative sources, and using contextual and environmental information in decision processes.

Progress:
This contract is new in FY92.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: H-46 Transmission Health Monitoring - Seeded Fault Testing

PRINCIPAL INVESTIGATOR: Anthony Duthie
Westland Helicopters, Inc.
(703) 696-4504

R&T PROJECT CODE: z44h020 CONTRACT NO:

Objective:
The objective is to provide vibration data from faulted gearboxes running on a test rig in order to critically test neural net pattern recognition technology.

Approach:
H-46 gearbox components will be provided to contractor. Contractor will modify test stand to accommodate this gearbox and run it with a minimum of 8 faulted component types at two levels of damage, and monitor and record accelerometer data in both analog and digital format.

Progress:
This contract is new in FY92.

Outside Funding:
Funds for this project are provided by NAVAIR.

TITLE: Intelligent Processing of Epitaxial Materials Using OMCVD

PRINCIPAL INVESTIGATOR: Ronald P. Gale
Kopin Corporation
(508) 824-6696

R&T PROJECT CODE: a44m001 CONTRACT NO:

Objective:
The objective is to implement a fully functional intelligent processing methodology for the organometallic chemical vapor deposition process for preparing epitaxial device structures.

Approach:
A supervisory control loop will be implemented that encompasses all aspects of an OMCVD process from incoming materials to product inspection. The epitaxial deposition process will be integrated with advanced controls, including: real-time material measurements made in situ, theoretical modeling of system response, including neural network analysis, and modern control system for the epitaxial deposition process. A photovoltaic device will be used as the development vehicle for the advanced control system, and a heterojunction bipolar transistor will be the primary application of the intelligent control approach.

Progress:
This contract is new in FY92.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Mechanisms Underlying the Generation and Coordination of Oscillatory Neuronal Responses in Cat Visual Cortex

PRINCIPAL INVESTIGATOR: Charles M. Gray
The Salk Institute
Vision Center Laboratory
(619) 453-4100

R&T PROJECT CODE: 4426321 CONTRACT NO: N0001491J1256

Objective:
The objectives of the proposed research are to provide answers to these two questions: 1) Do oscillatory neuronal responses recorded in spatially separate locations of the visual cortex, selectively synchronize when stimulated by the coherent motion of the contours of a discrete visual object? 2) What mechanisms underlie generation of neuronal oscillations and the coordination of this activity within separate locations of visual cortex?

Approach:
The PI will conduct neurophysiological experiments in cats in close con-junction with realistic neuronal network simulations of the visual cortex. Data gathering and simulations will target three specific hypotheses for mechanisms thought to underlie the generation of oscillatory responses.

Progress:
The PI has developed a set of detailed compartmental models of single neocortical pyramidal cells. Models are closely linked to the available morphological and physiological data describing two classes of pyramidal neurons.

Report:
Jagadeesh, B., Gray, C., Ferster, D. (1992). Visually evoked oscillations of membrane potential in cells of cat visual cortex. Science (in press).

Gray, C., Aguilar, R., Corley, D. (1992). A visual stimulation and data acquisition system for multi-electrode recording experiments in the visual system. Journal of Neuroscience Methods (in press).

TITLE: Demonstration of Neural Network Performance for On-Line Health Monitoring and Inspection of Aircraft

PRINCIPAL INVESTIGATOR: Gail A. Hickman
Innovative Dynamics
(607) 257-0534

R&T PROJECT CODE: 400e132 CONTRACT NO: N0001491C0094

Objective:
Innovative Dynamics proposes to implement neural network signal processing software on their aircraft Health Monitoring System (HMS) testbed. Structural abnormalities are determined via attached sensor arrays, distributed processors, and independent signal processing software modules. Neural networks will be compared with conventional classification algorithms in making decisions about the input.

Approach:
Extend research on HMS testbed by implementing neural network software for performance comparison with current pattern recognition system for monitoring/inspecting rivet line corrosion.

Progress:
Phase 1 SBIR demonstrated testbed integration for the analysis of structural vibration measurements for damage detection using neural network techniques. Phase 2 will examine system on Navy fighter aircraft components in wind-tunnel experiments.

TITLE: *An Investigation Into the Advantages of Periodically Correlated Signal Assumption for the Helicopter Vibration*

PRINCIPAL INVESTIGATOR: William Y. Huang
Naval Ocean Systems Center
(619) 553-6566

R&T PROJECT CODE: 4426520 CONTRACT NO: N0001492WX24082

Objective:
The objective is to develop the best combination of signal processing algorithm and classifier for classifying impending faults in helicopter gearboxes from vibration data.

Approach:
Vibration data, including the Hollins and Westland gearbox data, will be analyzed using periodically-correlated spectral estimation, Wigner-Ville algorithm, and various classifiers , and evaluated with respect to their ability to enhance detection and classification of mechanical faults or impending faults. Software previously developed at NOSC for P.C. spectral processing will be translated to C for application to this data. Additionally the robustness of various time-frequency transforms will be evaluated on this data. Earlier work on neural net and statistical classifiers will be extended to include the Lynch-Granger hierarchical classifier.

Progress:
A data set of features extracted from acoustic transients is being tested with the Lynch-Granger classifier. Modifications in the code are in progress. Analysis of the Hollins data set with cyclostationary spectral methods did not produce a separation of fault and no-fault cases.

TITLE: FASEB Summer Research Conference on Biology, Chemistry and Modelling of Vision: Visual Processing

PRINCIPAL INVESTIGATOR: Michael J. Jackson
Federation of American Soc. for Exper. Biology
(301) 530-7000

R&T PROJECT CODE: 400h110 CONTRACT NO: N0001492J1392

Objective:
Progress continues to be made in understanding information processing in the retina. This conference will bring us closer to the stage where biologically realistic models of the retina can be formulated and tested for their generality and applicability.

Approach:
Conference will bring together about 150 research workers for intense scientific discussions over a five day period. Thirty-four speakers have agreed to present their work at the formal morning and evening sessions. Other participants will present their work in afternoon poster sessions. A special fund has been organized to support new, young investigators.

TITLE: Characterization of Ground Squirrel Retina Ganglion Cells

PRINCIPAL INVESTIGATOR: Nidza Lugo-Garcia
University of Puerto Rico
Medical Sciences Campus
(809) 721-4149

R&T PROJECT CODE: 4426205 CONTRACT NO: N0001489J3070

Objective:
Determine the retinal projection pathways in the central nervous system responsible for color vision. Incorporate these pathways into a functional architecture describing visual information processing.

Approach:
Conduct a series of experiments to (1) characterize the dendritic arborization of cells projecting to different central nervous system areas, and (2) determine if retinal ganglion cells project to more than a single target area. Also, nerve growth factor (NGF) will be assayed in an attempt to influence growth patterns in neural cultures.

Progress:
Three types of retinal ganglion cells have been characterized. The two types responsible for color vision (opponent-color and contrast-sensitive) do not interact until thalamic and collicular levels. Glutaminergic transmission seems to be present, but is modifiable with a number of peptides known to exist in the retina. More exact colocalization remains to be done.

Report:
Lugo-Garcia, N. and Blanco, R.F. (1992). Localization of GAD- and GABA-like immunoreactivity in ground squirrel retina: retrograde labeling demonstrates GAD-positive ganglion cells. Brain Research, 564, 19-26.

TITLE: Machinery Diagnostics Using Polynomial Neural Networks

PRINCIPAL INVESTIGATOR: B. E. Parker
Barron Associates, Inc.
(804) 985-4400

R&T PROJECT CODE: 400e149 CONTRACT NO: N0001492C0060

Objective:
The technical objective is to develop and evaluate signal preprocessing and inductively-learned neural network recognition techniques that will allow machinery to be monitored.

Approach:
The PI will identify and implement signal processing for filtering diagnostic signal parameters and feature extraction for classification, develop a fault detector, and implement a multi-class classifier using polynomial neural networks. Classification performance will be evaluated on ONR-supplied helicopter gearbox data.

Progress:
This contract is new in FY92.

TITLE: Optical Oil Debris Monitoring

PRINCIPAL INVESTIGATOR: John F. Reintjes
Naval Research Laboratory
Laser Physics Branch
(202) 767-2175

R&T PROJECT CODE: z44h021 CONTRACT NO: N0001492WX24289

Objective:
The objective is to develop an optical imaging system for real-time detection and classification of particles in flowing oil in order to monitor the status of machinery such as turbine engines.

Approach:
An optical imaging system, using a pulsed laser, produces images of particles in flowing oil as shadows on a CCD camera. Issues to be addressed include laser wavelength and power, the value of using two orthogonal viewing directions, spatial resolution capability, volume coverage and field of view, and the degree to which metal chips can be identified in the presence of air bubbles and other contaminating matter. The images will be made available for neural network image processing and object recognition.

Progress:
This work request is new in FY92.

Outside Funding:
Funds for this project are provided by NAVAIR.

TITLE: Neural Net (NN) Technologies

PRINCIPAL INVESTIGATOR: James Solinsky
Science Applications International Corp.
(619) 546-6007

R&T PROJECT CODE: a44b001 CONTRACT NO: N0001489C0241

Objective:
The objective is to advance the state of neural network technology for automated sonar classification and to evaluate the performance of these systems.

Approach:
An analysis will be performed of the methodologies involved in comparative performance measurements and related statistics for detection and classification of specific acoustic signals. Evaluations will be made of SAICs hybrid screener/neural net classifier and the Orincon system on signals of interest for surveillance. The range sensitivity of minimum detectable signals will be evaluated for these automated neural net techniques.

Progress:
Developed an automated neural net classifier system with the following components: Signal preprocessing, event screening, feature extraction and neural net classifier. Polyspectral techniques were employed as detectors, and backpropagation neural nets were compared with statistical classifiers and a novel network called stochastic cellular automata. Data sets 1 and 2 were analyzed with this system and neural nets were found to enhance the overall system performance.

Report:
Solinsky, J.C. and Nash, E.A. (1991). Neural network performance assessment in sonar applications, Proc. IEEE OES Conference on Neural Networks for Ocean Engineering.

Outside Funding:
Funds for this project are provided by DARPA and SPAWAR.

TITLE: Synaptic Computations for Target Ranging in Biosonar

PRINCIPAL INVESTIGATOR: Nobuo Suga
Washington University
Department of Biology
(314) 889-6805

R&T PROJECT CODE: 4426502 CONTRACT NO: N0001490J1068

Objective:
The long term objective is to arrive at description of the neural mechanism for performing cross-correlation analysis of pulse and echo for range discrimination in an echolocating bat.

Approach:
The approach will be to describe the synaptic mechanisms underlying target ranging by delay-dependent multiplication in FM-FM combination sensitive neurons of the auditory cortex. Specifically, this will be examined in terms of (1) neural delays, (2) nonlinear multiplication and (3) determinants of delay tuning. The encoding of (4) target size will also be investigated. Specific hypotheses will be tested by the microiontophoretic application of neuroactive agents onto sites in the thalamus and cortex where these mechanisms are implemented. This will provide a direct test of computational mechanisms inferred from single-unit physiology, using behaviorally relevant stimuli.

Progress:
The functional role of excitatory receptors in generating the nonlinear multiplication required for temporal correlation by delay-tuned neurons has been characterized. Summation of fast non-NMDA EPSP's performs coincidence detection, while summation of non-NMDA receptor depolarization results in NMDA receptor activation. The long duration of NMDA EPSP's allows a burst at best delay, converting a probability of firing into a rate code. The voltage dependence of the NMDA receptor allows this burst without losing the narrow delay tuning.

Report:
Riquimaroux, H., Gaioni, S.J. and Suga, N. (1991). Cortical computational maps control auditory perception. Science, 251, 565-568.

TITLE: Optical Imaging of Neuronal Mechanisms for Visual Perception and Behavior

PRINCIPAL INVESTIGATOR: Daniel Y. Ts'o
Rockefeller University
(212) 327-8000

R&T PROJECT CODE: 400x095 CONTRACT NO: N0001491J1865

Objective:
First, to develop a new optical imaging procedure based on monitoring intrinsic brain voltages that will be compatible for use in awake, behaving primate studies. Second, to determine the mechanisms of preattentive and attentive visual search in primate visual cortex with the aid of optical imaging. Third, to observe changes in cortical activity patterns during the learning of a visual task.

Approach:
The new methodology involves the acquiring of frames by a host computer from a slow-scan CCD camera. These frames are images of the cortex illuminated by 630nm light. Near-infrared illumination may also be used due to the greater penetration of infrared light through tissue. Behavioral tasks will be performed with awake, restrained monkeys trained (and monitored)to maintain fixation in the visual field during stimulus presentation. Matching-to-sample, eye saccade responses, and reaction time measurements all briefly describe the behavioral approach.

Progress:
Progress has been made in the development of an optical imaging procedure for the in vivo chronic animal preparation. A procedure that will allow the implant of a long-term chamber on the skull including an artificial dural membrane is undergoing testing. The PI has conducted experiments probing the temporal characteristics of the intrinsic optical signals correlated with brain activity.

Reports:
Roe, A.W. and Ts'o, D.Y. (1992). Functional connectivity between V_1 and V_2 in the primate. Abstracts of the Society for Neuroscience, 18, 327.

Reid, R.C. and Ts'o, D.Y. (1992). Color receptive fields in macaque V_1: the spatial and temporal structure of isolated cone inputs. Abstracts of the Society for Neuroscience, 18, 723.

TITLE: Comparative Performance Measurements for Continuous Speech Recognition by Neural Networks

PRINCIPAL INVESTIGATOR: Alex Waibel
Carnegie-Mellon University
School of Computer Science
(412) 268-7676

R&T PROJECT CODE: a44b004 CONTRACT NO: N0001491J1131

Objective:
The objective of this research is to develop a continuous speech recognition system that uses artificial neural networks, and compare its performance with systems based on other techniques.

Approach:
Linked modules of Time-Delay Neural Networks will be extended for speaker-independent speech recognition at the acoustic/phonetic level, and hybrid neural and hidden Markov methods will be examined at the word level. The best use of connectionist (neural) and classical recognition techniques for speaker-independent large-vocabulary continuous speech will be evaluated using standard speech databases.

Progress:
A hybrid connectionist system was extensively tested on a connected speech recognition task. A Multi-state Time-Delay Neural Network was developed and tested on a speaker-dependent task, producing an error rate 1/2 of that of the Sphinx system. Several connectionist systems have been implemented for large vocabulary continuous speech recognition, with best results being obtained for an LVQ based NN hybrid. Neural nets have been implemented in the iWarp massively parallel computer, with a 20 times speed up. A connectionist language parser has also been developed which learns automatically from text.

Report:
Zeppenfeld, T. and Waibel, A. (1992). A hybrid neural network, dynamic programming word spotter. In: Proc. IEEE International Conference on Acoustics, Speech and Signal Processing, March 1992.

Outside Funding:
Funds for this project are provided by DARPA.

TITLE: Cortical Adaptive Filtering in Bioacoustic Signal Classification

PRINCIPAL INVESTIGATOR: Norman M. Weinberger
University of California, Irvine
Center for the Neurobiology of Learning
(714) 856-5512

R&T PROJECT CODE: 442m100 CONTRACT NO: N0001491J1193

Objective:
The objective is to determine the extent to which training-induced adaptive filtering in the auditory cortex can contribute to optimum acoustic signal classification.

Approach:
This research combines neurophysiological recording from auditory cortex with learning of acoustic discriminations in guinea pigs. The behavioral experiments have been designed to characterize adaptive filtering in the presence of noise, in the presence of target and non-target signals, sensitivity to context, and with complex acoustic signals. The paradigms and analysis of neuronal responses have been adapted to test specific models of signal classification in the auditory system.

Progress:
Basic analyses of the adaptive filtering properties of inputs to auditory cortex were completed. Medial geniculated (MGv) neurons exhibited adaptive filtering only over 1/8 octave range and for 1 hr. By contrast MGm neurons showed adaptive filtering over their entire frequency range and for days. In cortical recording session, successful 2 tone discrimination has been performed. During this discrimination, auditory cortical neurons can shift from multipeak frequency response to single peaked at the trained (CS+) frequency.

Report:
Edline, J.M. and Weinberger, N.M. (1991) Thalamic short-term plasticity in the auditory system: Associative retuning of receptive fields in the ventral medial geniculate body. Behavioral Neuroscience, in press

BIOLOGICAL INTELLIGENCE

NEURAL CONTROL OF LOCOMOTION AND MOVEMENT

TITLE: Connectionist Modeling of Basal Ganglia Motor Circuitry

PRINCIPAL INVESTIGATOR: Garrett E. Alexander
Emory University
Department of Neurology
(404) 727-5004

R&T PROJECT CODE: 4426444 CONTRACT NO: N0001492J1132

Objective:
The objective is to develop a neural network model of the motor circuitry of the primate basal ganglia in order to clarify the role of this system in the control of directed, multi-joint limb movements.

Approach:
A computer simulation of the basal ganglia motor control system will be developed with connections having variable weights adjustable on an activity dependent basis. This model will incorporate anatomical and physiological data. The modeled basal ganglia motor circuitry will be incorporated into a working simulation that controls multi-joint limb movements in a virtual 3-D workspace. The performance of this system will be compared with a motor control system lacking the specific connections of basal ganglia.

Progress:
The simulation of a multi-joint limb has been implemented in software, and an x-windows input/output interface has been developed so that the limb's movements can be controlled by the connectionist networks that are soon to be constructed. Design and specification of the software for the model of basal ganglia circuitry is completed.

Report:
Alexander, G. (1992). Neurophysiology of motor systems: coming to grips with connectionism. Behavioral and Brain Sciences, in press.

TITLE: Neural Networks for Real-Time Sensory Data Processing and Sensorimotor Control

PRINCIPAL INVESTIGATOR: Randall D. Beer
Case Western Reserve University
Departments of Computer Engineering & Science
(216) 368-2816

R&T PROJECT CODE: 4426420 CONTRACT NO: N0001490J1545

Objective:
The objective of the proposed research is to elucidate the principles by which invertebrate nervous systems control locomotion behavior, and to apply this understanding to the design of more autonomous, flexible, and robust hexapod robots.

Approach:
A detailed computer model of the neural circuitry and periphery (plant) involved in the cockroach escape response will be developed. This simulation will provide an interactive medium for synthesizing results of experimental and theoretical tests of system operation. In order to demonstrate that biological control principles can be applied to robotic design, the grantees will also construct a hexapod robot, and a locomotion controller based upon a neural model under development.

Progress:
1. Experimental Work: The basic leg movements in meso- and metathoracic legs have been analyzed during turns. Movements at the joints of the prothoracic legs were found to be more complex, similar to a ball and socket joint. A study of the current-frequency relationship of ventral giant neurons was completed, and has been incorporated into the model. 2. Modeling and Simulation: The current model of the giant interneurons incorporate numerous physiological features. Physical dynamics are being incorporated into the kinematic model of the insect body. This dynamic model will be flexible enough to allow segments and joints to be changed as model evolves. Automatic construction of adaptive neural controllers is being pursued by use of genetic algorithms to evolve continuous time recurrent neural network controllers for chemotaxis and locomotion. 3. Robotics: A 6-legged robot under control of locomotion neural net has been built.

Report:
Beer, R.D., Kacmarcik, G.J., Ritzmann, R.E. and Chiel, H.J. (1991). A model of distributed sensorimotor control in the cockroach escape turn. R. Lippman, J. Moody & D. Touretzky (eds) Advances in Neural Information Processing Systems V.3, Morgan Kaufmann.

TITLE: Biomechanics of Locomotion in Invertebrates: Musculo-Skeletal Dynamics in Response to Environmental Perturbations

PRINCIPAL INVESTIGATOR: Robert J. Full
University of California, Berkeley
Department of Integrative Biology
(510) 642-9896

R&T PROJECT CODE: 4426530 CONTRACT NO: N0001492J1250

Objective:
The objective is to obtain quantitative data on the musculo-skeletal dynamics of legged invertebrates during performance tests.

Approach:
The approach is to obtain quantitative measures of the 3-D kinetics and kinematics of legs affected by alterations in gravity vector, irregularities in substrata, and during obstacle negotiation, turning and rotation. The research will also address the general mechanisms of whole body movement and "effective" leg function during environmental perturbations and the trade-of between using static or dynamic stability during such perturbations.

Progress:
Produced the first 3-dimensional description of a multi-legged running and climbing insect. Performed analysis of climbing movements. Developed a photoplastic track for the first measurement of simultaneous ground reaction forces in all legs. Provided kinematic analysis to M.I.T. robotics lab resulting in improved design of robotic legs, permitting robots to use same motions in climbing and flat terrain.

Report:
Full, R.J. (1992). Integration of individual leg dynamics with whole body movement in arthropod locomotion. In: Biological Neural Networks in Invertebrate Neuroethology and Robotics, Eds.: R. Beer, R. Ritzman, and T. McKenna, Academic Press, in press.

TITLE: Adaptive Control of Limb Motion by Brains and Robots

PRINCIPAL INVESTIGATOR: James C. Houk
Northwestern University
Department of Physiology
(312) 908-8219

R&T PROJECT CODE: 4426126 CONTRACT NO: N0001490J1822

Objective:
The objective is to advance knowledge about how the cerebellum might mediate adaptive feedforward control, and to apply this information to robotics.

Approach:
The investigators will conduct computer simulations of motor systems, in the form of simulated neural networks, that are based on the anatomy and physiology of the cerebellum. More specifically, the investigators are interested in the functional and computational significance of the findings that will result from the mapping of mossy-fibre inputs to cerebellar cortex. Consequently, the investigators will develop and simulate networks of neuron-like units whose architectures and roles in motor control are based on anatomical and physiological knowledge.

Progress:
PI has extended previous model of an individual cerebellar adjustable pattern generator module to an array of APGs whose collective activity controls movement of a simple two-degree-of-freedom simulated limb. Simulation experiments show that the model is capable of learning to control the simulated limb.

Report:
Miller, L.E., Sinkjaer, T., Andersen, T., LaPorte, D.J. and Houk, J.C. (1992). Correlation analysis of relations between red nucleus discharge and limb muscle activity during reaching movements in space. In: Experimental Brain Research supplement; Control of Arm Movement in Space: Neurophysiological and Computational Approaches. R. Caminiti, P.B. Johnson and Y. Burnod, ed. Springer-Verlag. In press.

TITLE: Neural Networks for Autonomous Motor Control

PRINCIPAL INVESTIGATOR: Michael Kuperstein
Symbus Technology Inc.
(617) 232-8266

R&T PROJECT CODE: 400e113 CONTRACT NO: N0001491C0258

Objective:
The objective is to implement and build a single-jointed robotic arm and controller for positioning unforseen payloads with accurate and stable movements.

Approach:
The proposed implementation will be based on a working computer simulation that has been shown to achieve autonomous adaptive control. The neural arm has been designed to adaptively control any number of sensory inputs with links of any number of joints. The feedforward nature of control will allow parallel implementation in real time across multiple joints.

Progress:
Phase 2 code development for studying the coupling effects between joints in a multi-jointed robot continues. Demonstration of a Puma arm intercepting a moving object shown at Navy Neural SBIR meeting, May, 1992.

TITLE: Synaptic and Network Determinants in Insect Sensory-Motor Circuits

PRINCIPAL INVESTIGATOR: Giles Laurent
California Institute of Technology
Division of Biology
(818) 397-2798

R&T PROJECT CODE: 4426430 CONTRACT NO: N0001491J4118

Objective:
The objective of this study is an experimental and modelling analysis of the role of specific sensory-motor circuits in the generation of locomotion and the execution of adaptive reflexes in legged invertebrates.

Approach:
In the first project, synaptic efficacy between spiking and non-spiking neurons in locust thoracic ganglia will be examined by paired intracellular recordings between pre and postsynaptic neurons. Measures of synaptic release will be obtained for multiple postsynaptic neurons receiving input from the same presynaptic neuron. This approach will address the question of whether an interneuron releases transmitter with the same efficacy at all synapses. The second project will use realistic simulations of small neural nets to evaluate the neurons role in local reflexes and sensory-motor mapping in limb control. The third project will combine electrophysiology, modelling, and VLSI implementations of neural circuits in order to understand how the central pattern generators are coordinated in walking.

Progress:
The synaptic transfer made centrally by one interneuron upon different target neurons varies due to difference in release probabilities. Intrinsic rhythms of hemiganglia controlling locomotion show different intrinsic frequencies, and are coupled most strongly with neurons controlling contralateral antagonists.

Report:
Laurent, G. & Sivaramakrishnan, A. (1992) Single local interneurons in the locust make central synapses with different properties of transmitter release on distinct postsynaptic neurons. Journal of Neuroscience 12, 2370-2380.

TITLE: Center for Neural Engineering

PRINCIPAL INVESTIGATOR: Mohan J. Malkani
Tennessee State University
School of Engineering and Technology
(615) 320-3550

R&T PROJECT CODE: 4426206 CONTRACT NO: N0001492J1372

Objective:
To provide an enhanced research environment by combining talents at two historically black institutions. Neural network research will be the focus around which the efforts will revolve.

Approach:
A consortium (Tennessee State University, Meharry Medical College, Oak Ridge National Laboratory, Accurate Automation Inc.) has been formed to support basic research on neural network systems while providing exposure of this area to a new generation of minority students.

Progress:
This grant is new in FY92.

TITLE: Intelligent Controls Research Using the Dexterous Robotic Hand and Neural Networks Laboratory

PRINCIPAL INVESTIGATOR: Robert McLauchlan
Texas A&I University
Department of Mechanical Engineering
(409) 845-1264

R&T PROJECT CODE: 4421200 CONTRACT NO: N0001491J1365

Objective:
The objectives are to (a) develop new strategies for intelligent control of robotic arm-hand systems, (b) develop a new graduate research program in intelligent control.

Approach:
The investigators will develop new software simulations of control algorithms and neural network/fuzzy logic systems for controlling (a) an experimental 2-link arm/scissor hand system and (b) a Remotec arm plus Salisbury/JPL dexterous hand system. Hierarchical neural nets and fuzzy logic will be examined for computing inverse dynamics, torque control, and sensor integration. An autonomous machine vision system will also be implemented and integrated with the robotic control systems.

Progress:
Four research assistantships have been awarded in intelligent controls and two additional grad students received partial support. A complete syllabus has been developed and submitted for approval for a Ph.D program on Systems, Controls and Signal Processing. A multi-link, 2D movement, modular experimental arm/hand system has been designed for grasping/ capture research. M.S. thesis projects completed include: (1) motion planning with neural nets for a 2 link arm with scissor hand, (2) neural visual inspection of circuit boards, (3) a simulator for the Stanford/JPL hand, and (4) fuzzy logic and neural control of industrial thermal systems.

Report:
Omar, SI and Chang, H. (1991) An algorithm for edge detection suitable for automatic visual inspection of printed circuit boards. Tech. Rep. ICSL-91-08

TITLE: From Animals to Animats: Second International Conference on the Simulation of Adaptive Behavior

PRINCIPAL INVESTIGATOR: Herbert L. Roitblat
University of Hawaii
Psychology Department
(808) 956-6727

R&T PROJECT CODE: 4426280 CONTRACT NO:

Objective:
The objective is to conduct a scientific meeting on simulation of adaptive behavior: "From Animals to Animats: Second International Conference on the Simulation of Adaptive Behavior".

Approach:
The conference will bring together researchers in ethology, ecology, cybernetics, artificial intelligence, robotics and related fields so as to further our understanding of adaptive autonomous systems. The unifying theme of the conference is to explore how animal behavior leads to the development of more sophisticated approaches to robotic performance and how utilizing ideas and methods form robots and AI can aid in comprehending animal behavior.

TITLE: Computational Functions of Neostriatal Neurons

PRINCIPAL INVESTIGATOR: Charles J. Wilson
University of Tennessee
Department of Anatomy and Neurobiology
(901) 528-5233

R&T PROJECT CODE: 442n100 CONTRACT NO: N0001492J1113

Objective:
The objective is to use accurate biophysical data on membrane nonlinearities to identify the mechanisms of quasistable membrane phenomena, and determine the effect of this mode of synaptic integration on neuron computations.

Approach:
Computer simulations will be conducted to determine what effect realistic membrane properties of neurons have on integration of realistic patterns of synaptic inputs. The effects of individual currents, and their interaction will be examined. Six currents will be examined: fast inward rectifier, delayed rectifier, transient K, slow transient K, fast Na, and high threshold Ca current. Computer simulations will determine the essential ionic mechanisms of the quasi-stable subthreshold behavior seen in vivo, and determine how these nonlinear mechanisms produce a filter on the spatio-temporal patterns of synaptic input.

Progress:
Obtained data on the kinetics and voltage sensitivity of 3 currents and incorporated them into model neurons. A slowly-adapting potassium conductance was found to confer computationally significant properties to the neuron: the ability of nearby synapses to act cooperatively is dependent upon the history of prior synaptic input to the dendrite over a period of seconds. Dopamine was found to regulate sodium channel inactivation, and hence patterned discharge of the neurons. Simulations of the interactions of currents have revealed three membrane potential ranges with distinct resistivities.

Report:
Surmeier, D.J., Xu, Z.C., Wilson, C.J., Stefani, A. and Kitai, S.T. (1992). Grafted neostriatial neurons express a late developing transient potassium current. Neuroscience 48: 849-856.

MANPOWER, PERSONNEL, AND TRAINING RESEARCH AND DEVELOPMENT PROGRAM

TITLE: An Improved Measure of Reading Skill

PRINCIPAL INVESTIGATOR: Bruce K. Britton
Univ. of Georgia Research Foundation, Inc.
Department of Psychology
(404) 542-1806

R&T PROJECT CODE: 4428041 CONTRACT NO:

Objective:
The objective is to develop an improved measure of reading comprehension ability.

Approach:
The primary approach will be the use of a technique for measuring cognitive structure by rating perceived relatedness of concepts. Such measures will be taken before and after reading a relevant passage. A diverse set of passages will be used so that background knowledge can be expected to vary for each subject. Analyses will include investigating the relationship of the novel measures of comprehension ability so derived with existing conventional measures of reading comprehension ability.

Progress:
This project is new in FY 92.

TITLE: Job Knowledge Test Design: A Cognitive Science Approach.

PRINCIPAL INVESTIGATOR: Walter C. Borman
Personnel Decisions Research Institute
(813) 974-2492

R&T PROJECT CODE: 4428035 CONTRACT NO: N0001491C0224

Objective:
The objective of this project is to explore the viability of improving Marine Corps job knowledge tests by applying methods from modern cognitive science.

Approach:
Job knowledge tests for three Marine Corps domains will be developed and evaluated with job trainees and job incumbents. A key ingredient of the evaluation will be the relationship between measures of job knowledge and measures of hands-on performance. To this end, domains will be selected for which job performance measurement instruments have been developed, and the relationships between performance on the two types of tests will be studied.

Progress:
An extensive literature review has been completed and first drafts of the measurement instruments and administrative manuals have been completed. Other aspects of the work, primarily cognitive analyses of the land navigation task, have been delayed by problems in obtaining information and making arrangements for site visits to the Marine Corps.

TITLE: Computer-based Tests of Cognitive Abilities in Time-Pressured Decision Making

PRINCIPAL INVESTIGATOR: Thomas F. Sanquist
Battelle Memorial Institute
(206) 525-3130

R&T PROJECT CODE: 4428036 CONTRACT NO: N0001492C0062

Objective:
The objective of the proposed research is to evaluate the predictive power of computer-based tests of cognitive abilities in the millisecond range on complex decision-making involved in simulations of air traffic control and emergency dispatch (911) tasks. A primary product will be the development of a method for assessing individual differences in cognitive abilities necessary to carry out complex mental operations required in modern command and control environments.

Approach:
Standard psychometric and newly-developed computer-based measures of cognitive abilities will be compared and used to predict performance under time pressure on simulations of air traffic control and emergency response dispatch (911) tasks. The performance of expert air traffic controllers and emergency response dispatchers on these cognitive tests will be evaluated to determine the validity of the measures and the nature of information-processing by experts in these tasks. The effects of extended practice on naive subjects will also be evaluated.

Progress:
This project is new in FY92.

TITLE: Manpower Research and Advisory Services

PRINCIPAL INVESTIGATOR: H. W. Sinaiko
Smithsonian Institution
Manpower R&D Program
(202) 357-1829

R&T PROJECT CODE: 4428032 CONTRACT NO: N0001489C0093

Objective:
This contract provides for applied research, expert consultation, and working groups to supplement contract research programs in cognitive and neural sciences. It provides quick reaction responses to research problems associated with manpower and personnel issues in naval operations.

Approach:
Continuing research support to the programs of the ONR Manpower R&D Committee is provided in such areas as computerized adaptive testing, human resources modeling, investigations of personnel attrition, retention and innovative training technologies.

Progress:
Conferences and workshops on the following topics were conducted: 1) Advances in Biopsychometric Assessment Research; 2) New Directions in Decision Making Research; 3) Instructional Systems for Maintenance Training; 4) Economical Multifactor Research Strategies; 5) Locomotion Control in Legged Invertebrates; 6) Model-Based Psychological Measurement. In support of transitioning products of the MPT research program, successful demonstrations were conducted of a tutor/simulator for teaching complex, dynamic systems.

Report:
Govindaraj, T. J. (1991). Simulated environments for instruction in science and engineering. Georgia Institute of Technology. Sinaiko, H. W. (1991). Technical Panel UTP-3, Military Human Resource Issues. Washington, D.C.: The Technical Cooperation Program.

TITLE: Development of Intelligent, Computerized Aids for the Specification of Causal Models from Large Data Bases

PRINCIPAL INVESTIGATOR: Peter Spirtes
Carnegie-Mellon University
(412) 268-8571

R&T PROJECT CODE: 4428027 CONTRACT NO: N0001491J1361

Objective:
This project aims to develop reliable computerized methods of formulating "multiple indicator" causal models of datasets with large numbers of variables. These will be incorporated in the existing TETRAD II program of artificially intelligent aids to causal modeling of correlational data. The methods will be applied to Navy personnel record databases.

Approach:
In order to reduce the problem of dealing with datasets with very large numbers of variables, it will be assumed that variables can be clustered on substantive grounds into multiple indicators of a smaller number of latent variables. Methods will be developed for testing the appropriateness of this clustering. New heuristic search techniques will be developed to improve the capability of searching for plausible models of such more complex datasets. Graph theoretic techniques will be used to identify causal models which are not, in principle, distinguishable on the basis of the correlational data.

Progress:
The work of this project is nearly complete. Methods for clustering variables to give relatively pure measures of latent variables were successfully developed as planned. Experimental explorations showed that there are instances in which the structural modeling performed by TETRAD correctly gives results which are not only different in magnitude from those of traditional regression analysis but also different in the direction of influence. Updated software and documentation for TETRAD will soon be delivered to NPRDC.

TITLE: Automating a Detailed Cognitive Task Analysis For Structuring Curriculum

PRINCIPAL INVESTIGATOR: Kent E. Williams
Virginia Polytechnic Institute & St. Univ.
Dept. of Industrial & Systems Engineering
(703) 231-4051

R&T PROJECT CODE: 4428031 CONTRACT NO: N0001491J1500

Objective:
This project aims to produce an automated aide to the process of analyzing a to-be-trained task at the production system level of detail so that a subject-matter expert who is not trained in computer and cognitive science will be able to accomplish such an analysis, a prerequisite to the production of an artificially intelligent training system for that task.

Approach:
The approach will be to automate the process of analysis that was used in the PI's previous successful project building a tutoring system. Analysis is based on a production system theory of the nature of human skill. For example, goals, subgoals, and tasks contributing to the accomplishment of goals are specified. Then methods are specified for the accomplishment of tasks, methods being a set of steps or conditions to be satisfied in accomplishing the task. This analysis process will continue until a set of primitive operations in the vocabulary of the automated aid is reached.

Progress:
An initial version of the cognitive analysis tool has been completed and a users' manual prepared. A current issue for resolution in future development is how to generalize the GOMS model to handle task situations in which interrupts occur, leading to a more complex task hierarchy in contrast to a simple strict hierarchy. Williams was enlisted as a collaborator in a successful SBIR proposal to SPAWAR, which is leading to a realistic possibility that this system will be used in new training systems that SPAWAR is going to be developing.

UNIVERSITY RESEARCH INITIATIVE: DECISION MAKING IN HIERARCHICAL TEAMS

TITLE: Effective Team Performance Under Stress and Normal Conditions

PRINCIPAL INVESTIGATOR: Daniel R. Ilgen
Michigan State University
Department of Psychology and Management
(517) 355-7503

R&T PROJECT CODE: uri5206 CONTRACT NO: N0001490J1786

Objective:
The objective is to learn about modifiable factors in the selection of team members, in the design of team tasks, and in the training of team members that influence the effectiveness of team performance in decision making under conditions of uncertainty.

Approach:
Behavioral experiments will be conducted in which teams work on complex coordinated decision making tasks over extended periods of time. Time series analyses of team characteristics and performance will be done, taking into account the individual difference characteristics of team members, social factors within the group, and the cooperation and coordination requirements of the assigned tasks as variables. Stress will be manipulated by work overload and loss of normally available information.

Progress:
The project has developed and made available to other researchers a networked software program called TIDE2 for scientific studies of team decision making. The program is quite flexible with respect to the scenarios which can be programmed and allows for non-team application also. Subprograms provide for collecting, sorting and analyzing data. Many hundreds of subject hours have been collected for this project, using this program. Two book chapters reporting the research are in preparation.

Report:
Hollenbeck, J.R., Sego, D., Ilgen, D.R. & Major, D. (1991). Team interactive decision exercise for teams incorporating distributed expertise (TIDE2): A program and paradigm for future research. Technical Report.

TITLE: Contingent Coordination in Naval Team Decisionmaking

PRINCIPAL INVESTIGATOR: David L. Kleinman
University of Connecticut
Dept. of Electrical & Systems Engineering
(203) 486-3066

R&T PROJECT CODE: uri5201 CONTRACT NO: N0001490J1753

Objective:
The objective is to determine how hierarchically organized teams can most effectively coordinate their communication and action in response to varying time and workload stress and the availability of communications channels.

Approach:
Normative mathematical models of theoretically optimum behavior in these situations have been developed in previous work. An appropriate simulation of the decision making task environment has also been developed. In order to determine the relationship between this theoretical analysis and actual human behavior, behavioral experiments with 3 and 4 person teams will be conducted in the simulation environment. Time stress and workload will be varied, as will the availability of communication channels and the specified organizational structure dividing responsibilities among team members.

Progress:
Experiments were conducted with 4-person hierarchical teams to study the effects of time pressure on the team's coordination process. Resource allocation tasks in an air defense scenario required coordination for optimal performance. Time pressure affected team communication patterns, and increased reliance on the team leader for coordination.

Reports:
Wang, W., Luh, P.B., Serfaty, D. and Kleinman,D.L.(1991) Hierarchical team coordination in dynamic decision making. Proceedings of the 1991 IEEE/SMC Conference. Charlottesville, VA.

Pete, A., Pattipati, K.R. and Kleinman, D.L. (1992). Team relative operating characteristics: Normative-descriptive model of team decision making. IEEE Transactions on Systems, Man and Cybernetics, April 1992.

TITLE: The Effects of Organizational Structure on Distributed Human Decision Making Under Uncertainty

PRINCIPAL INVESTIGATOR: Paul E. Lehner and Alexander H. Levis
George Mason University
Dept. of Information Systems & Engineering
(703) 993-1625

R&T PROJECT CODE: uri5202 CONTRACT NO: N0001490J1680

Objective:
The objective is to identify and characterize variables that enhance coordination of tactical decision-making teams and enable teams to maintain coordinated action under the stressful conditions characteristic of tactical environments.

Approach:
A mathematical model of team communication and coordination, predicting performance in a tactical decision-making task, will be used to drive the design of behavioral experiments that test key features of the model. Experiments will explore the impact on team performance of task complexity, of the kinds of information that can be exchanged among decision-makers, of time and workload stress, of the allocation of tasks between humans and computers and of the use of decision aids.

Progress:
A two-layered Petri Net model of team decision making reveals the dynamic interactions among team members as determined by rules embedded in the Coordination Layer. The model enables explicit modeling of variations in coordination strategies.

Report:
Lu, Z. and Levis, A. H. (1991) A Colored Petri Net model of distributed tactical decision making. Proceedings of the 1991 IEEE/SMC Conference, Charlottesville, VA.

TITLE: Hierarchical Group Decision Making: A Multidisciplinary Approach

PRINCIPAL INVESTIGATOR: Alan M. Lesgold
University of Pittsburgh
Learning Research and Development Center
(412) 624-7045

R&T PROJECT CODE: uri5205 CONTRACT NO: N0001490J1664

Objective:
The objective is to determine how the process and outcome of group decision-making are affected by members' task-relevant experience as both individuals and team members and by the availability and clarity of task-relevant information.

Approach:
Experiments will be conducted in which groups work together for extended periods of time in performing a demanding simulated air-traffic control and intruder detection task, accessing information and communicating with each other via networked computer workstations. Type of hierarchical organization and personnel turnover will be experimentally varied. Detailed records of interaction will be collected and analyzed. Parallel computer simulations will both model this behavior and explore a wider range of variables and levels of each variable than is feasible in the experimental laboratory.

Progress:
A group decision laboratory has been established and the software for task presentation and communication control developed. The network package for group experimentation runs of Novell networks with central data logging into a Btreive database. However, persistent technical problems with the network have been experienced when communications channels are selectively closed for experimental purposes. The theoretical simulation work of Carley has progressed well and provides hypotheses which await testing when these technical difficulties are overcome.

Report:
Carley, K. (1991) Coordination for effective performance during crises when training matters. Technical Report.

TITLE: Studies of Crew Coordination and Performance in Hierarchical Team Decision Making

PRINCIPAL INVESTIGATOR: Ben B. Morgan
University of Central Florida
Department of Psychology
(407) 275-2216

R&T PROJECT CODE: uri5203 CONTRACT NO: N0001490J1846

Objective:
The objective of this project is determine what types of organizational structures in hierarchical teams, and what detailed behaviors of team members serve to promote coordination and team effectiveness in such complex and demanding team tasks as tactical decision making.

Approach:
Behavioral experiments will be conducted in which hierarchically organized teams carry out synthetic team tasks designed as analogues to the requirements of real Navy jobs, as determined by task analyses. Multi-platform tactical decision-making will be among the tasks simulated. Detailed recordings of communications and other behavior will be made and analyzed. Type of hierarchical structure and workload stress will be experimentally varied.

Progress:
A Team Performance Assessment Battery (TPAB) was developed and refined in pilot studies with 5-person teams. Experiments are planned to explore effects of communication structure, workload, and information uncertainty on team performance.

Report:
Morgan, B.B. and Bowers, C.A. (1991)Teamwork stressors; implications for team decision making. Conference Proceedings:Team Decision Making in Organizations, University of Maryland, College Park, MD.

TITLE: Information Flow and Decision Making in Teams Under Threat

PRINCIPAL INVESTIGATOR: Garold L. Stasser
Miami University
Department of Psychology
(513) 529-2415

R&T PROJECT CODE: uri5204 CONTRACT NO: N0001490J1790

Objective:
The objective is to determine how types of team organization and communications affect team performance effectiveness in a tactical decision making situation, to identify communication strategies that are associated with effective performance, and to determine whether those strategies can be trained to good effect.

Approach:
Seven-person teams will be engaged in an uncertain tactical decision making task comparable to the Vincennes incident. Recording and mathematical and computer simulation modeling of information transmission, dispersion and redundancy will be done. Based on a decision theoretic analysis of the task, a measure of sensitivity will be computed to index the degree to which the team's actions reflect the implications of the available information. The impact of variations in permitted communications links will be explored. Using data from both records of communications and self reports, communication strategies associated with effective performance will be identified. Experiments in which those strategies are trained will be conducted.

Progress:
The laboratory was established and the software for presenting the decision-making task and controlling communications for experimental purposes has been successfully developed. Although hardware failures have delayed the progress of data collection, data for 21 seven person teams have now been collected.

STRESS AND PERFORMANCE

TITLE: Improving Problem-solving and Decision-making Skills Under Stress: Prediction and Training

PRINCIPAL INVESTIGATOR: Philip L. Ackerman
University of Minnesota
Department of Psychology
(612) 624-0288

R&T PROJECT CODE: 4421575 CONTRACT NO: N0001491J4159

Objective:
Proposed experiments will use stress reactivity and cognitive and perceptual abilities to predict performance under stress on a Navy-relevant analogue to the combat information center (CIC) environment. The effects of training on decision-making under stress will be evaluated with respect to the allocation of limited cognitive and perceptual resources during periods of high situational demand.

Approach:
Measures of stress reactivity and cognitive and perceptuo-motor abilities will be correlated with performance on a single-operator command and control training simulation and compared to global measures of performance existing in the military record, e.g., overall job performance, the ASVAB, attrition, promotions, disciplinary actions, etc. Attentional processes in decision-making strategies will be assessed by self-report and used to develop training interventions to counter the effects of stress on performance.

Progress:
Work has begun developing a Navy-relevant target/threat identification task for use with Navy recruits.

Outside Funding:
Funds for this project are provided by the ONT, TADMUS program.

TITLE: Behavioral and Pharmacological Analysis of the Inverted-U Relationship Between Corticosterone and Hippocampal Plasticity

PRINCIPAL INVESTIGATOR: David M. Diamond
University of Colorado Health Sciences Center
Department of Pharmacology
(303) 399-8020

R&T PROJECT CODE: 4421572 CONTRACT NO: N0001491J1753

Objective:
The proposed research will identify the neuropharmacological mechanisms underlying stress-induced changes in synaptic plasticity in the rat hippocampus and investigate putative behavioral correlates through the study of hippocampal-mediated memory processes.

Approach:
Neurophysiological, neuropharmacological and behavioral studies of the awake rat will relate experimentally-induced changes in serum corticosterone levels and synaptic plasticity to changes in memory performance. Corticosterone levels will be manipulated by novel environments, chronic infusion of a corticosterone inhibitor, or by adrenalectomy, subcutaneous corticosterone pellets and receptor ligands. Memory will be tested with an 8-arm radial maze task.

Progress:
Experiments show that psychological stress in the form of repeated exposures to different environments can be used to disrupt synaptic potentiation in successive sessions. These physiological effects were associated with increased levels of serum corticosterone. Other experiments indicated that dexamethasone, a glucocorticoid Type II receptor agonist, also disrupted synaptic potentiation.

Report:
Bennett, M. C., Diamond, D.M. and Fleshner, M. (1991). Serum corticosterone level predicts the magnitude of hippocampal primed burst potentiation and depression in urethane-anesthetized rats. Psychobiology, 19, 301-307.

TITLE: Stress Effects on Corticosterone, Cognitive Performance and Hippocampal Plasticity

PRINCIPAL INVESTIGATOR: Howard B. Eichenbaum
University of North Carolina at Chapel Hill
Department of Psychology
(617) 235-0320

R&T PROJECT CODE: 442j150 CONTRACT NO: N0001491J1881

Objective:
The PI will assess the effects of moderate transient stressors (i.e. restraint, environmental novelty) or direct pharmacological manipulation of corticosterone on plasma corticosterone levels, hippocampal-dependent learning, and learning-induced enhancements of hippocampal synaptic efficacy. A second objective is an examination of the behavioral effects of the above-mentioned manipulations using olfactory paradigms known to engage hippocampal function.

Approach:
The rodent olfactory-hippocampal system provides an excellent model of the neurobiological bases of mammalian cognitive performance in general and the effects of transient stressors in particular. Behavioral paradigms for rats will be developed that assess cognitive functions similar to those known to depend on intact hippocampal function in humans. Levels of stress on pharmacological indices of stress will be manipulated and hippocampal-dependent physiological and behavioral functions will be probed and monitored.

Progress:
Preliminary results showed that (1) rats could be trained on an olfactory test of transitive inference; (2) Fornix transection disrupted this transitive inference ability; (3) the degree of hippocampal synaptic enhancement correlated with performance accuracy during the acquisition of an odor recognition skill in rats; (4) restraint prior to daily training retarded acquisition of the task; (5) similar restraint improved the accuracy of rats previously trained to associate paired odors.

TITLE: Development and Enhancement of a Model of Performance and Decision Making Under Stress in a Real-Life Setting

PRINCIPAL INVESTIGATOR: Colin F. MacKenzie
University of Maryland at Baltimore
Department of Anesthesiology
(301) 328-3418

R&T PROJECT CODE: 4422568 CONTRACT NO: N0001491J1540

Objective:
The objective is to produce a process model of medical decision-making in a real-life stressful medical task environment of trauma patient resuscitation and anesthesia. The effects of various stress factors such as fatigue and patient workload upon the quality of decision performance will be determined.

Approach:
Model building will begin with considerations derived from task analyses and decision trees based on expert judgment of ideal decision performance. The model will be evaluated, refined and modified based on the analysis of performance data obtained from the analysis of videotapes of real trauma patient resuscitation and anaesthesia. Stressors in the task environment will be identified and their effect on team and individual performance will be measured. The effects of fatigue, mental workload, and team interaction in sharing and shedding tasks, and the effect of physicians' experience will be investigated.

Progress:
After the initial start-up phase in which equipment was acquired and a satisfactory videotape coding system located and purchased, the hardware and software configurations for both video data acquisition and data analysis have been finalized. Six trauma patient admissions have been taped for use in establishing video analysis procedures and a draft analysis protocol has been developed. A fatigue assessment battery has been obtained from NPRDC for use by trauma staff after taped sessions.

Report:
Mackenzie, C.F. Simulation of trauma anesthesia. Chapter to appear in "Textbook of Trauma Anesthesia and Critical Care."

TITLE: Stress Effects on Performance: Potentiation or Attenuation?

PRINCIPAL INVESTIGATOR: Tracey J. Shors
Princeton University
Department of Psychology
(609) 258-5696

R&T PROJECT CODE: 4421576 CONTRACT NO:

Objective:
The proposed research tests the notion that acute stress induces long-term potentiation in the rodent hippocampal complex, affecting hippocampal function thereby enhancing classical conditioning and disrupting the acquisition of spatial information. The behavioral effects of stress will be measured and their neuropharmacological and neurophysiological mechanisms will be identified.

Approach:
The effects of minimal physical stressors on synaptic plasticity and AMPA/quisqualate receptor binding in the rodent hippocampus will be measured with direct electrophysiological recordings in behaving rats. The effects of stress and stress hormones on long-term potentiation and memory will be measured during neuropharmacological and surgical manipulations. Behavioral measures will include eye-blink conditioning and performance on radial arm mazes.

Progress:
This grant is new in FY92.

TITLE: Construction of Tests Sensitive to Dysfunction of Human Hippocampus

PRINCIPAL INVESTIGATOR: Larry R. Squire
University of California, San Diego
Department of Psychiatry
(619) 534-3330

R&T PROJECT CODE: 4421574 CONTRACT NO: N0001492J1350

Objective:
The principal objective is to measure the effects of stress and individual differences in stress reactivity on hippocampal-dependent memory processes by constructing and administering an appropriate cognitive test battery to Navy personnel during stressful and non-stressful phases of Navy training.

Approach:
Correlate patterns of test results with individual differences in stress reactivity as measured by hormonal and personality assessments in order to test the predictive validity of such measurements on performance under stress.

Progress:
This grant is new in FY 92.

TITLE: Stress Reactivity: A Psychobiological Typology of Performance-Relevant Individual Differences

PRINCIPAL INVESTIGATOR: Ross R. Vickers
Naval Health Research Center
(619) 553-8454

R&T PROJECT CODE: 4421565 CONTRACT NO: N0001492WR24012

Objective:
The objectives of the proposed research are: 1) To determine whether dichotomous typologies or dimensional classification schemes are appropriate theoretical approaches to describe individual differences in stress reactivity; and 2) to use behavioral and/or physiological markers to predict the performance of individuals under stressful or non-stressful conditions.

Approach:
During the initial phase, self-report behavioral measures and hormonal markers for hypothalamic-pituitary-adrenal/gonadal activity will be used to define individual differences in stress reactivity. Later phases of study will evaluate the predictive validity of these classifications on job performance and perceptual and cognitive test performance during and after basic training.

Progress:
Preliminary cluster analyses of NEO Personality Inventory data obtained from 3,328 Naval recruits indicated that recruits could be sorted into stress reactive, stress resistant, and stress neutral categories. Stress reactive recruits were more likely and stress resistant recruits were less likely to leave basic training after an acute medical stressor (n=334). This trend was evident in an unselected population of recruits (n=1548). Stress resistant recruits, as measured by the NEO inventory, had much lower basal cortisol levels, greater cortisol elevations during stressful periods of basic training, and no change in natural killer cell activity between high-stress and low-stress periods. The stress resistant recruits were distinguished from all other groups on these measures. These results demonstrate the utility of personality measures in predicting individual performance under stress.

INDEX

CONTRACTORS

INDEX

PRINCIPAL INVESTIGATORS

INDEX

R&T PROJECT CODE